SILICON CHIP

AUGUST 2016
ISSN 1030-2662
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BUILD IT

Arduino® Compatible Wi-Fi Scanner

This is a simple tool using just four Duinotech parts that can quickly tell you what Wi-Fi networks are nearby and their relative strengths. If you're always working with different Wi-Fi networks like us, or have a few Wi-Fi Shields (XC-4614) running in hotspot mode, it's handy to know which networks are up and which are not. Features:

- Displays 5 most powerful Wi-Fi networks nearby
- Automatic update every 5 seconds
- Shows relative strength
- No soldering needed

SEE STEP-BY-STEP INSTRUCTIONS AT jaycar.com.au/diy-arduino-wifi-scanner

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XC-4410

XC-4616

XC-4614

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XC-4430
Alternatively, the Leonardo development board is also an option for this project. Most of the Duinotech models use two chipsets, one for the main controller, one for USB communication. The Duinotech Lite combines both these functions into a single IC. This lowers the cost, and opens to door for more advanced USB functions.

- 75(W) x 53(L) x 13(H)mm

ADD ON

Stackable Header Set for Arduino® HM-3207
To create a more rigid assembly, solder together two of the eight-way headers from the Stackable Header Set.

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Most Arduino® type shields use regular "male" pin headers for connection to the Arduino®. Using stackable headers instead allows you to stack shields on top of each other and use multiple shields at the same time. We supply the stackable headers in a pack to suit Arduino® type shields with the latest "R3" headers.

- Gold flash 0.1 pitch quality stackable headers

Includes:

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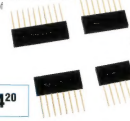
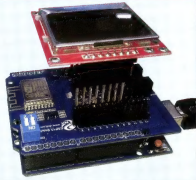
- 1 x 2x3-pin (for ICSP)



$4.20

The following photo shows how the Wi-Fi Scanner looks when it is assembled using the Stackable Header Set (HM-3207) to give a more compact arrangement. Note how we only use the last seven pins of the header adapter so that the LED pin is not connected.



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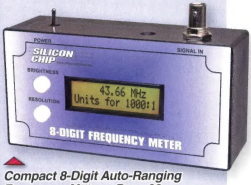

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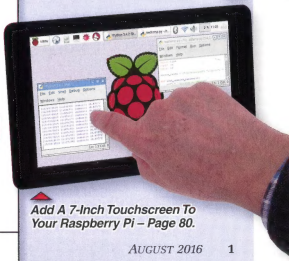

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SILICON CHIP
www.siliconchip.com.au

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SILICON CHIP is published 12 times a year by Silicon Chip Publications Pty Ltd. ACN 003 205 490. ABN 49 003 205 490. All material is copyright ©. No part of this publication may be reproduced without the written consent of the publisher.

Printing: Offset Alpine, Lidcombe, NSW.

Distribution: Network Distribution Company.

Subscription rates: $105.00 per year in Australia. For overseas rates, see our website or the subscriptions page in this issue.

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ISSN 1030-2662
Recommended & maximum price only.

Publisher's Letter

Digital technology is blanketing us with RF hash

Few people would argue against the efficiency and compact size of switchmode power supplies compared with conventional supplies using iron-cored transformers. A typical switchmode supply will run at around 85% efficiency or better, while a conventional supply is typically 40% efficient or a lot worse. Switchmode supplies are also much more compact and weigh less.

And nor would anyone argue against the advances brought about by digital data transmission, whether it is used in mobile phones, digital TV broadcasts or internet data via cable or phone connections. But without changes, all this wonderful technology means that AM radio broadcasts, in Australia and everywhere else around the world, will eventually become unusable.

This fact was rammed home to me as I drove home one evening this week. As I came abreast of a bike rider, I noted that his flashing LED headlight was completely blanketing the AM radio on 702kHz. It sounded like speech - sheeschhhh – speech - scheeeschh . . . The light was really bright but I am sure the rider knew nothing about the rubbish he was radiating.

In fact, all AM broadcasts below 1MHz are similarly blanketed if I drive near the local telephone exchange and several other pockets on my short journey home. Then, when I drive into my garage, there is another source of hash (which I have yet to locate) which plays havoc with reception.

Inside my house, several CFL (compact fluorescent lights) radiate rubbish so if I want to listen to AM radio I have to orientate the receiver for best reception. In my nearby neighbour's home, AM is unusable and the only way she can listen to her preferred stations is via a DAB+ radio. All of this occurs in an area where the AM signal is reasonably strong. In weaker signal areas, this hash means that AM is unusable unless you can resort to a loop antenna or an external antenna above the roof line.

Sure, if you have a DAB+ receiver, you can listen to that but DAB+ is only available in the capital cities and there are plenty of areas where its signal strength is "below the digital cliff".

What can radio listeners do about these problems? While they might be able to control sources of interference in their homes, switching off certain appliances at the wall when they are not in use, their courses of action are quite limited. And nor can much be done about interference sources outside the home.

Clearly, this situation requires action but the responsible body in Australia, ACMA, seems to be quite inactive in the face of the flood of imported products which are supposed to conform to radiated EMI standards but don't. At one time, many years ago, when the Post Master General was in control of radio broadcasts and reception, they were quite vigilant about detecting and eliminating sources of radio interference. Why cannot ACMA at least move in that direction?

It would not be a huge task for ACMA to have small teams of radio inspectors who could do surveys around cities and towns to locate sources of bad interference. The spectrum analysis equipment required is cheap, readily available and easy to use. With interference sources located, remedies can surely be proposed and implemented. In fact, ACMA could accelerate the detection process by letting the public log into their website to pinpoint bad locations.

And as for switchmode equipment with bad interference, it does not have to be this way. ACMA only needs to inspect and reject a small number of products and publicise the facts, for improvements to come about. Without any action, AM broadcasts will die.

Leo Simpson

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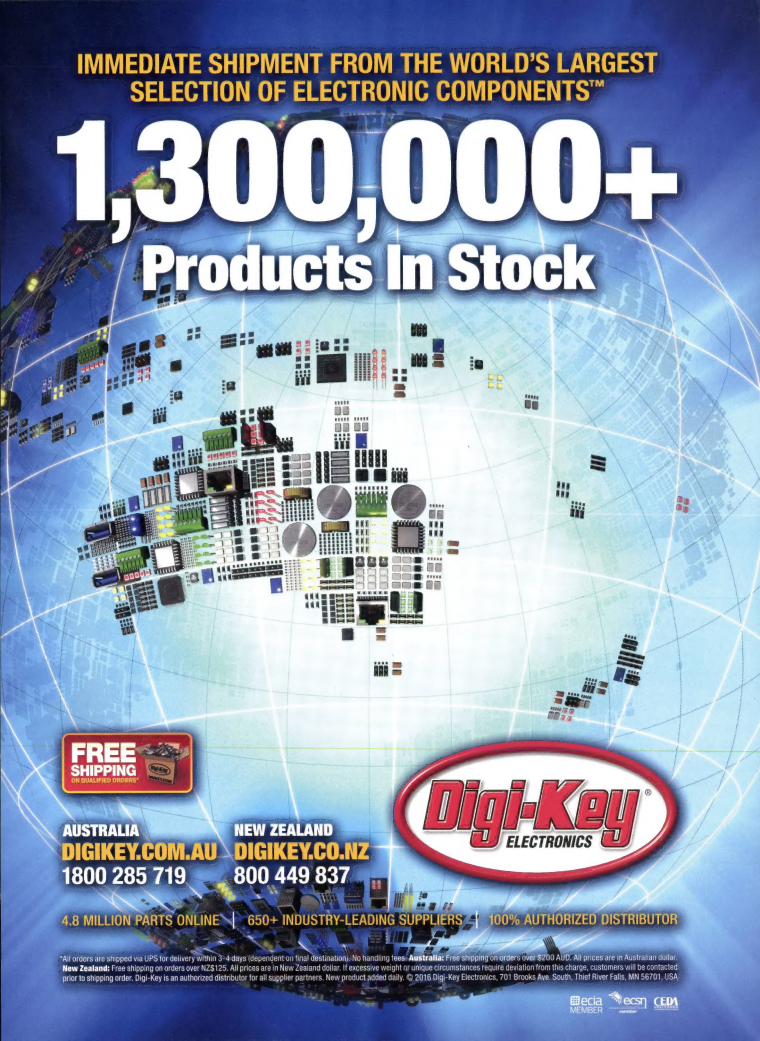

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MAILBAG

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Wiring faults in a new home

In early 2007, we bought a project home in Brisbane and moved in on May 27th, 2007. It is a single-level four-bedroom open-plan design with the usual features and fittings, including electric garage doors.

At that stage, I had not taken any particular interest in the electrical configuration and/or the switchboard. Almost immediately, we added a shed on a sub-switchboard and a 3-phase ducted air-conditioner. Starting in late 2007, we had several unexplained power outages due to an RCD tripping and they typically affected a group of GPOs at the front of the house – in the garage, laundry, office and kitchen.

We would lose power to the garage doors, kitchen fridge, second fridge (in the laundry) and the phones and modems in the office. Everything else remained on. The usual outcome was spoiled food, difficulty in gaining access to the house and general inconvenience. I started to do some fault-finding but could not ascertain any patterns. I would unplug everything and reconnect one appliance at a time to see what caused the outage but with no result.

I also called an electrician to do some checks, including leakage tests on the refrigerators during defrosting. All passed.

We reconfigured the switchboard into more circuits to try to isolate appliances and we discovered evidence of a fire and overloading in the switchboard wiring. This was determined as not related to the additions of the shed and air-conditioner, so the switchboard was rewired and cleaned up.

We had more outages, so additional RCDs were fitted and a more comprehensive reconfiguration of the switchboard was done. Still more occasional outages. In May 2016, we had two outages within a week or so so and due to some more serious inconveniences, we called a relative who has an electrical business.

We decided that we would analyse the problematic circuit in detail until the problem was identified and that analysis focused on reading resistances from Active to Neutral for the entire circuit with no devices connected and then removing and testing GPOs, testing the circuit at each GPO point, progressively replacing GPOs and re-testing, and so on.

We established that several GPOs had surprisingly low resistance from Active to Neutral (within Australian Standard requirements but well short of the very high resistance that is typical of good, safe GPOs/switches). We had GPOs that would read, say, 40 megohms and then with a shake of the GPO or an operation of the switch, they would read almost zero ohms (Active to Neutral). Some GPOs even had a fracture in one of the corners where the screw is inserted to fix the mechanism to the front plate. If all fixing points failed, then on plug insertion the mechanism could break away from the front plate and that could have serious consequences.

An overseas visitor had brought a power board (made in China) and it was faulty/dangerous although it was working. Its resistance reading was too low. When all GPOs were changed and the faulty power board removed, the Active/Neutral resistance reading at the switchboard was higher than any of our test instruments could measure.

This is not the first time I have dismantled Chinese-made electrical equipment such as power drills, bench

In-depth explanation of programming not desired

This letter is in response to your query following Cliff King's letter in the Mailbag section of the July 2016 issue (page 6).

SILICON CHIP treads a fine line between "popular" magazines and being too technical to be a marketable product. Two other letters in the Mailbag illustrate being "in the right place": (1) Grant Saxton's piece on HP calculators and (2) Neil Harris' story on the 2650 microprocessor are excellent examples of what I believe your marketplace is.

Your projects using microcontrollers should spend some article space discussing the programming, for example, some aspect of cleverly dealing with a particular case, but only with enough code to make your point. If readers are not interested, they can skip those paragraphs or text boxes. If they want to see all the code, they can download it.

Perhaps SILICON CHIP could host a Wiki for the Micromite? We would forgive you running advertising material in the Wiki! There are many programming resources online.

For the Arduino, the Playground provides numerous starting points for all sorts of applications. These are very basic examples and would surely be an acceptable starting point for a non-programmer who is prepared to spend a bit of time on the site. It can be criticised for containing much code that appears to be incomplete, with two main faults: some of the libraries used in the examples have been superseded and the code is very often poorly constructed, in particular not well structured, which is a bad failing in a teaching environment.

www.stackoverflow.com is a great resource for resolving specific programming problems but it's not the place to learn programming from scratch. And neither is an electronics magazine.

Kevin Shackleton,
Leeming, WA.

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12SB30P	12	30	166	126	178	178	10.1	M5 Bolt & Nut	Dual Purpose
12SB34C	12	34	197	131	159	170	10.5	M5 Bolt	Dual Purpose
12SB38C	12	36	197	131	159	168	10.7	M6 Bolt	Cyclic
12SB40CL	12	40	196	166	171	171	13.1	M6 Bolt	Dual Purpose
12SB50C	12	50	196	166	171	171	14.3	M6 Bolt	Cyclic
12SB55CL	12	55	225	135	207	214	17.0	M6 Bolt	Dual Purpose
12SB65CL	12	65	350	166	174	174	21.6	M6 Bolt & Nut	Dual Purpose
12SB75CL	12	75	260	170	202	205	24.0	M6 Bolt	Dual Purpose
12SB100CLS	12	100	306	168	208	214	30.5	M6 Bolt	Dual Purpose
12SB110CL	12	110	330	170	212	215	32.5	M6 Bolt	Dual Purpose
12SB130CL	12	130	352	170	276	276	43.0	M6 Bolt	Dual Purpose
12SB150CL	12	150	352	170	276	276	46.0	M6 Bolt	Dual Purpose
12SB200CL	12	200	522	238	219	222	66.5	M8 Bolt	Dual Purpose
GEL Type									
12GB7C	12	7	151	65	94	102	2.7	F1 (Faston 187)	Cyclic
12GB12C	12	12	151	98	93	98	4.0	F2 (Faston 250)	Cyclic
12GB17C	12	17	181	76	167	167	6.3	M5 Bolt & Nut	Cyclic
12GB24C	12	24	166	175	125	125	9.5	M5 Bolt & Nut	Cyclic
12GB35C	12	35	197	131	159	159	12.1	M5 Bolt	Cyclic
12GB50C	12	50	166	166	171	171	14.5	M5 Bolt	Cyclic
12GB55C	12	55	226	135	207	214	17.0	M5 Bolt	Cyclic
12GB65C	12	65	350	166	174	174	23.9	M6 Bolt & Nut	Cyclic
12GB75C	12	75	260	170	202	205	24.8	M5 Bolt	Cyclic
12GB100C	12	100	306	168	208	215	34.0	M5 Bolt	Cyclic
12GB150C	12	150	500	110	288	288	50.0	M8 Bolt	Cyclic

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Mailbag: continued

Switchmode supply hash affects Micromite Garage Parking Assistant

Having seen the July issue and feedback in Ask Silicon Chip (on page 99) on the Garage Parking Assistant, here is my experience with the kit.

The construction and configuration of the unit was straightforward and proceeded without any issues. I was able to program and test the operation without any errors while plugged into the USB port of my computer. I then tested it using a 5V USB battery pack on the dining room table and it performed correctly.

When I subsequently powered up the Garage Parking Assistant using a 5V USB plugpack after installing it in the garage, the distance measurement was very unstable and flicked across the entire range from 0-200mm and also read "device not found". I replaced the mains powered plugpack with the battery-powered USB supply and the distance measurement stabilised.

I removed the unit from the garage and took it back to the dining room table where I built it. When using the battery bank, the display was still completely stable.

Changing to the mains-powered USB supply caused the display to resume flicking across the range again. I tried all the mains-powered USB plugpacks I have and none worked. The plugpacks were either purchased separately or supplied with a device as the charger.

In all, I tried eight different plugpacks, all rated at either 1A or 2A, and all gave problems

While not testing with a CRO, I did notice that the output voltage of the battery-powered USB supply was exactly 5V whereas the plugpacks were 5.2V. I don't know if this was the problem.

I added a 1000µF capacitor across the supply to see if it would help but there was no change. I therefore decided to try a 7805 and built a 5V supply and powered it from 9-12V. I left the capacitor across the regulated 5V output.

This appeared to fix the problem on the dining table. The distance display was again stable and accurate.

I returned the Micromite Ultrasonic Parking Assistant to the garage and powered it up again. The distance measurement was much more stable but still jumping up and down by 5cm; still not good enough.

I thought RFI might be getting into the signal to and from the ultrasonic sensor. I replaced the lead to the ultrasonic sensor with a shielded and Earthed lead and the problem was finally solved. The Micromite Ultrasonic Parking Assistant has been running for about three weeks now and it is still stable and accurate.

Ian Hayes,
Helensburgh, NSW.

I am totally unsurprised that we have faulty mains fixtures made overseas and note that these are likely to be fitted to thousands of houses in Australia.

Ranald Grant,
Brisbane, Qld.

Editor's note: sadly the quality of GPOs, mains wiring and other related products has gone seriously downhill in the last few years. One of our employees recently replaced several name-brand GPOs where the plastic had fractured and almost totally come loose. The replacements looked identically flimsy. We don't understand how they can be approved for sale.

Then there's the huge recall of Infinity and Olsent-brand mains cable sold between 2010 and 2013 and installed in around 22,000 homes. The insulation used was not up to scratch and is degrading prematurely, leading to huge headaches for those who may have it in their walls. eCables brand wiring has also been recalled, again due to substandard insulation. And by now we would have all heard about the woman who was electrocuted by a faulty USB charger.

Clearly, standards and inspections need to be drastically improved to keep consumers safe.

Basslink failure & energy security

I must congratulate Leo Simpson for his Publisher's Letter in the June 2016 issue of Silicon Chip, proposing the use of nuclear energy for Australian electrical energy security. I cannot fault his arguments. In Tasmania we have been suffering the consequences of irrational energy supply thinking.

However noble the quest for green renewable energy, the practicalities are both complex and complicated, many interacting with unforeseeable consequences. Worse, when political economic interests aligned with naive "green" political active motivation, the scenario for Tasmania's present energy situation was set. Tasmania had the first casino in Australia and perhaps the state has a gambling problem. Without a second BassLink cable for security, it was a question of not if but when a serious problem would occur.

Although the technology to build and operate a HVDC cable was well

saws and so on, and found substandard and/or lethal wiring arrangements. One drill was marked as double insulated but when opened showed no evidence of double insulation, even by today's watered-down standards. It had gone faulty and was within a hair's breadth of electrocuting me in certain usage situations.

I also found cases where plastic used for mains insulation was about as thick as Glad Wrap and mains wiring that passed through a grommet with very poor insulation properties.

Coincidentally, in April one of our refrigerators went faulty; we discovered that food had warmed up and spoiled but the temperature indicator showed 3°C. It was not 3°C inside, however. This is a well-known problem with these refrigerators. It has taken some time to repair (about four weeks so far) and it is the fourth similar failure since 2007; a less-than-terrific record.

We will monitor things more closely now and consider changing the few remaining GPOs. I have not added up what all this cost but it must be many thousands of dollars. However, I don't want to become mercurially angry about the cost to us of somebody saving a few dollars on GPOs made at the lowest possible cost.

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SKU: LAJ-021
Price: $182.00 ea + GST

SparkFun GPS Logger Shield
The SparkFun GPS Logger Shield equips your Arduino with access to a GPS module, µSD memory card socket, and all of the other peripherals you'll need to turn your Arduino into a wonder logger.
SKU: SFC-047
Price: $69.00 ea + GST

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The Nitgen RS-232 serial fingerprint scanner is a powerful ADSP-BF531 Blackfin based system.
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SKU: ECS-020
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Prices are subject to change without notice.

Mailbag: continued

This photo shows the damage to the Basslink HVDC cable. A report into the probable cause of the damage is yet to be released.

established, the technology to find and repair a fault in a predictable, timely manner was lacking, with weather being the wild card, coming into play both on land and at sea.

The Hydro engineers deserve credit for implementing what must have been a pre-planned emergency supply using 200 1MW diesel units, just in the time provided by the last of the dam water stocks. This averted an extremely serious electrical energy shortage in a society which has been encouraged to be dependent on a plentiful supply of hydro-electric energy. BassLink has now been repaired but has yet to run at full power (at the time of writing).

When the BassLink cable was first commissioned, a risk analysis would have shown there was no shipping in deeper waters which would likely drag the bottom, so unless a ship sank or lost its anchor, the cable was safe or the damage point could easily be identified. However, the law was changed, allowing heavy deep-sea trawlers to access our waters, so the risk changed dramatically.

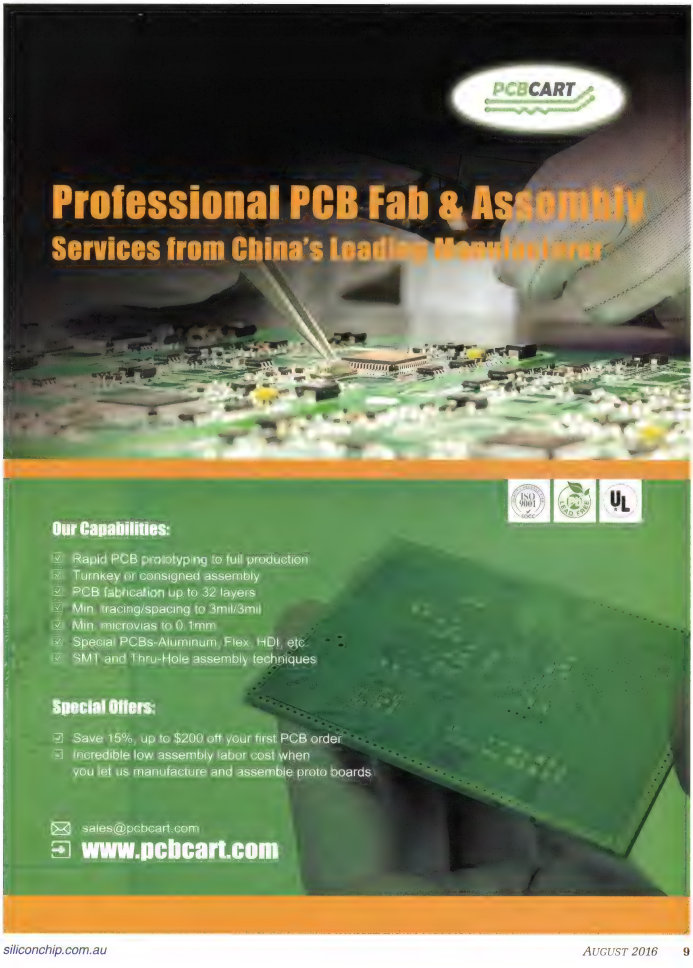
The official cause of failure is yet to be released, after "inconclusive tests" in Italy by the cable maker and now finally independent tests in the UK which apparently were able to determine the cause.

From mid-February, a fellow retired technician and I have followed the repair proceedings with great interest. Combined with my knowledge of high-voltage systems, when the picture of the faulty section of the cable was published (see photo), its appearance came as no surprise.

We also did some wider research reading sections on Federal Government reports on the cable's effect on Tasmanian energy. BassLink's triangular construction, with Active/return conductors and a fibre optic line, make the Active conductor more vulnerable to a west/east strike. We also researched the navigational laws for shipping to prevent cable strikes. These laws seem to be designed to prevent damage from shallow water shipping, where the cable has extra-heavy armour.

The photo suggests that the corner of a substantial mass clipped the cable at reasonable speed. The corner impinged on one strand of the armour, breaking it and pushing one loose end into the insulation. This created an electrical stress point which broke down the insulation, creating an electrical arc that caused a gas bubble.

With pressure still in force from the impact, the gas expanded the cable around that point. This would have happened in a few milliseconds before the protection systems sensed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Mailbag: continued

Parking Assistant problem solved

I have now resolved the problem with my Garage Parking Assistant, as mentioned in the Ask SILICON CHIP section of the July issue (page 99). I can confirm that the issue was the power supply. I have sourced a variety of 5V plugpacks from Australian suppliers but every one of them exhibited the same characteristics as the original unit and the Parking Assistant behaved the same way when using them. I tried inductors, ferrite cores and a variety of capacitors across the plugpack output as per your suggestions, with only minor improvements in all cases.

Ultimately, I constructed a small linear power supply with a transformer and one of the universal regulator PCBs that you designed, since I had it to hand. Using this source of 5V DC, the unit is completely stable and works very well.

This experience has confirmed my longstanding uncertainty about switchmode power supplies, especially in plugpacks. While it is undoubtedly possible to manufacture such a supply to give a clean DC output, the sad truth seems to be that no plugpack version of such a supply is adequate for sensitive usage. In reality, a linear supply is not a great deal more expensive but is greatly superior in performance and has the added bonus of being repairable in the event of failure.

None of the plugpack supplies that I tested had a clean DC output. All of them had varying levels of ripple and random spikes on the output and three of the five units were inaccurate in their output voltage. One plugpack which came with a Nokia phone actually produced 6V instead of the 5V claimed on the unit, both loaded and unloaded.

Thank you once again for your assistance with this project.

Barrie Davis,
Hope Valley, SA.

Comment: we have answered another letter on this topic in the Ask SILICON CHIP pages of this issue. It appears that the Micromite Parking Assistant is quite prone to switching noise in the supply rail and the only solution to is use a conventional (ie, non-switchmode) regulated 5V supply, as you have found.

the fault and tripped the cable. Naturally, we will be very interested to see whether the formal report backs up our analysis.

As Leo indicates, Australia's fossil-fuel power stations are being upgraded both for extended life and cleaner exhaust; in some cases, very significantly, giving most an extra 10-15 years of reliable operation. This is enough time to build a new, secure base-load system which better matches renewable energy systems and also does not emit carbon dioxide. Nuclear is the only generation system which currently fills these requirements.

Germany, one of the world's largest users of renewable energy, is reliant on the European continental grid network for its energy security, much of which is provided by French nuclear plants. Whilst political parties may be presenting a nuclear policy which does not offend the electorate, I have good reason to believe there are some politicians who have come to the realisation that we are between the devil and the deep blue sea concerning carbon dioxide emissions and energy security and that nuclear power is the only solution.

Kelvin Jones,
Kingston, Tas.

6V CDI modules commercially available

I have just seen the request for a 6V CDI for an Ariel Arrow in the Ask SILICON CHIP section of the March 2016 issue (on page 92). Pazon make an electronic bolt-in replacement for points for the 2-stroke Ariels. 6V and 12V versions are available – see www.pazon.com/ignition/altair-ignitions/

I have no affiliation with Pazon but may be a customer in the future.

Phil Gilgen,
Papamoa Beach, NZ.

CFLs can generate a great deal of interference

Recently, we had a problem with our Sky TV remote which not always triggering a response from the Sky box, or the function selected was not what was keyed in. The remote seemed OK; the red LED lit when a button was pressed and pulses could be heard when holding it close to an AM radio.

The Sky box has a blue receive LED which wasn't always flashing in unison with the remote's transmit LED. It looked like the fault was in the Sky box, meaning a call to Sky for a replacement. However, the same evening, I decided to replace a flickering ceiling-mounted CFL bulb. We then found that everything worked normally with the Sky remote! The CFL was about three metres from the Sky box by line of sight.

Apart from the visible flicker, it seems likely the faulty CFL was emitting some form of electromatic radiation, affecting the remote signal.

Tim Sanders,
Tauranga, NZ.

Editor's note: we have had correspondence in the past about CFLs either causing false triggering of infrared remote-controlled equipment or interfering with the operation of remotes. The CFL does not necessarily have to be faulty to cause these problems. The only sure way to avoid this dilemma is to make sure that light from CFLs does not fall on the infrared receiver window of any remote-controlled equipment.

Upgrading machine tool motors to 3-phase

In the Ask SILICON CHIP pages of the February 2015 issue, a reader from Mt Morgan was describing how a power surge on the mains damaged his milling machine's power supply (page 93).

This reminds me of living in Mt Morgan in the 1970s before the upgraded power feeder to the Moura coal mine was completed. Every time the drag line took a bite, the incandescent light bulbs in our house would dim and the black and white TV screen would shrink and then all would come good again until the next bite. So things do not appear to have changed much in the 40 years since then.

While I accept that money is often

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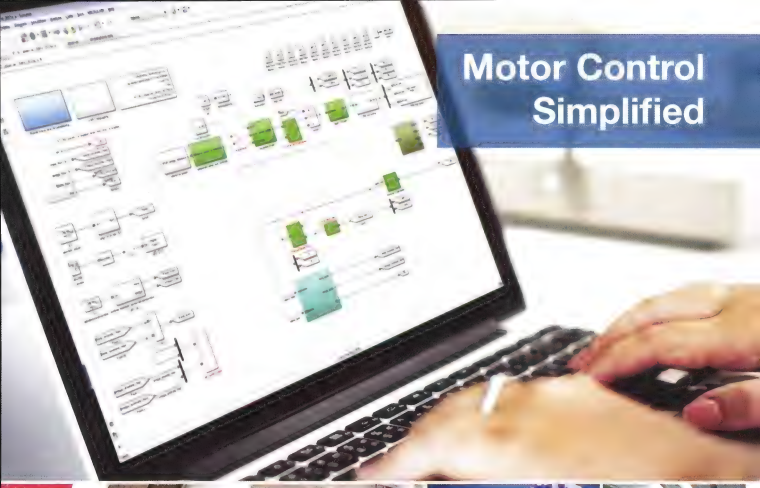

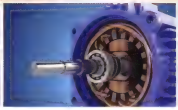

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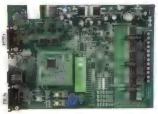

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Mailbag: continued

Energy storage for solar & wind preferred over nuclear power

I disagree with the Publisher's Letter on the topic of Small Nuclear Reactors, in the June 2016 issue.

Nuclear Power is a thermodynamic process in which water is boiled to produce steam which expands through a turbine generating electricity. Of course, the steam needs to be cooled to condense back to water. This calls for a lot of cooling water such that they tend to use seawater.

So think Fukushima. Think of Collaroy Beach, your postal address of SILICON CHIP, being washed away. Imagine you had persuaded the local council to build a small nuclear plant there. Northern Tasmania was hit by the storm too. Think Devonport. The ferries could not run but your nuclear plant may have survived.

The logical step following the thought that gee whiz the Sun isn't shining and the wind isn't blowing is not that we must start a generator but that we should store excess energy for those occasions. This is why 25 years ago Maria Scyllas Kazacos, now Professor at the University of New South Wales, started work on the vanadium flow battery.

Flow batteries separate the maximum power that can be produced, as determined by the size of the cell stack, from the quantity of electricity, determined by the volume of electrolyte. This was covered in EA or a predecessor along with other useful information. The other flow battery is the type that uses hydrogen and air/oxygen.

Engineer Bacon decided engineers needed to get involved so it was the Bacon Cell for a while. Now it is the alkaline fuel cell. Yes, engineers do need to get involved. Scientists get distracted.

The other suitable battery type is lithium-ion and provided not too many more catch fire (See RenEW magazine January-March 2016, page 14 regarding a house being burnt down), the entrepreneurs will do do well. Say $100 profit on a million domestic batteries gives $100 million profit.

Geoff Peverell,
Abbotsford, Vic.

Comment: solar power and battery storage may be a viable system for the Australian power grid at some time in the future. But no matter which battery type is suggested as the storage medium, such systems are presently many times more expensive than any base-load generation system, including nuclear power.

In any case, no-one in their right mind would suggest a seaside location for a small nuclear reactor and nor would such an installation require a huge cooling reservoir. A river or a lake would be suitable.

tight for those with home machine workshops, I would like to offer a suggestion for the speed control issue the reader had inflicted on him by the power surge. I replaced the single-phase induction motors on my lathe, drill press and milling machine with "new old stock" 3-phase motors and three new Omron 1.5kW variable speed drives (VSDs). The motors were $165 each and the Omron drives were on special for $215 each, including mains filters.

I should have done it earlier. The Omron help-line was actually really good, with experienced technicians, and they had me up and running in no time. This combination completely revolutionised the machines they drove. When chatter started whilst machining, a slight adjustment on the speed potentiometer caused the chatter to vanish. No more stopping and changing speeds by changing belts.

Tapping threads in any of the machines can now be done at a snail's pace by flicking the forward/reverse switch back and forth to advance the cut and clear the swarf. This was scary at first but so much quicker than doing it by hand. I am yet to brave the "torque out" set up and let the machines torque out when the tap bottoms out in the hole. I have seen this done without breaking the taps.

Neil Bruce,
Tarragindi, Qld.

Thorium reactors could solve energy supply issues

Congratulations on publishing the article on Small Nuclear Power Plants in the June 2016 issue. It describes the various types of reactors very well.

My particular interest is in the

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Molten Salt Reactor or LFTR. I sent a letter into SILICON CHIP back in December 2013 that was published in the Mailbag section where I outlined the benefits of the Molten Salt Reactor using the Thorium fuel cycle.

It certainly looks like a "no brainer" to use this type of reactor and I'm pleased to see some start-up companies (in Canada, Sweden, USA, India and China, to name a few) getting into the Thorium side of things. I believe that history will look back on the decision in the early 1970s by then US President Nixon to stop the Thorium Reactor program as a bad one. It had been running very successfully at Oakridge National Lab for many years but was stopped in favour of pursuing Light Water Uranium and Plutonium Breeder reactors.

If that program had kept going, the world would not be in such a pickle now. I believe there would be cheap power virtually everywhere by now, thus lifting a lot of third world countries out of poverty with the additional benefit of a more stable world, not to mention greatly reduced CO_2 emissions as modular MSRs would have reduced the dependency on coal/gas fired generators.

There are even more advantages in just using the heat output (desalinating water, producing replacement fuels, etc). I'll concede there are probably a few disadvantages but not many!

A growing body of scientists and academics in the USA have been lobbying the Congress for several years now, trying to get Thorium reclassified, to allow rare earth industries to start up again and end the monopoly from China.

Readers might find the numerous videos from the 7th annual TEAC (Thorium Energy Alliance Conference in USA) very interesting – see http://thoriumenergyalliance.com/ThoriumSite/TEAC7.html and https://youtu.be/0BybPPIMuQQ

Other interesting links from an Australian perspective are: https://youtu.be/IzbI0UPwQHg and https://youtu.be/4J06Vhlw52o

Hopefully, the world will transition in the coming years away from fossil fuels and move into the Thorium age for the next 1000 years of cheap, limitless power.

Greg Gifford,
Laguna, NSW.

Fossil fuel costs will continue to rise

The Publisher's July 2016 editorial on fossil fuels made many valid points but overlooked the most important issue – cost. The world has made great progress over the last 300 years by burning through 500 million years of concentrated solar energy, which has been available at ever-decreasing costs. However, this trend has now turned around and energy is becoming increasingly expensive to extract.

The up and down prices of oil only distracts from the reality that low-cost oil has all been used up. It is true that we will never run out of oil. It will just become costlier and out of the reach of an increasing number of people.

The Publisher's Plan A appears to be for some breakthrough in low-cost energy, and that we can continue to progress. I suggest that it would be prudent to have a Plan B, based on the assumption that energy is only going to

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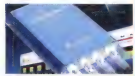

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Mailbag: continued

Enthusiasm for Micromite programming articles

Can I please add my request to that of Cliff King's (July 2016), asking for an article on programming the Micromite – for absolute dummies.

In the months following the article in the February 2016 issue on the Micromite LCD BackPack, I have learnt the following:

(1) "OPTION BAUDRATE" can be dangerous, if you set the baud rate to one that your serial port does not support; you may need to reprogram the PIC chip to recover.

(2) Using a PICkit 3 to reprogram the PIC32 is not as straightforward an operation as I would like. I kept getting a message indicating "no voltage detected on pin 2" and when I tried to connect the USB-to-serial adaptor to power the PIC during programming, I accidentally reversed the supply leads, resulting in smoke being released from the MCP1700.

(3) Replacing the MCP1700 with a smoke-filled model and applying red to the positive position resulted in my reprogrammed PIC32 having nothing in RAM and only one line in Flash memory. I had to re-load the Boat Computer program using said USB-to-serial converter.

(4) Programming statements like MM.Hres/2 and CM, 1,4 are completely beyond me but having loaded the Super Clock software into the unit, the clock works well!

(5) I had to carefully study the Boat Computer and Garage Parking Assistant code to realise that MM.Hres/2 cuts the screen in half, "CM" actually locates any text in the middle of the screen, that font 1 is the only font available to me, and the command rgb() changes the colours of various items.

(6) I have learned that the command "option reset" doesn't do what I expected and "NEW" does not reset the LCD options.

(7) I now realise that entering RS and EN in the "LCD init" command (as shown in the manual) does not result in reset and enable information appearing on any Micromite pin and that, in fact, I should probably replace those terms with numbers (somewhere in the mid-20s) to produce the desired result

I'm sure that many other realisations await me as I attempt to wrestle with such terms as DO and LOOP!

Seriously though, a guide to the absolute basics of BASIC would be appreciated. Or am I the only one that is having this kind of trouble?

Bill Winefield,
Perth, WA.

get more expensive and that we will have to adapt to a more frugal, energy-efficient and self-sufficient lifestyle.

Mark Baker,
South Perth, WA.

Renewable energy sources preferred over fossil fuels

With respect to the Publishers' Letter in the July 2016 issue, he really must leave the fossil fuels "fan club" ASAP!

Anybody with any common-sense must know that fossil fuels are a dead-end alley and that our future must be renewable-based. The July 2016 article on directional drilling, while technically fascinating, simply does not belong in an electronics technical journal such as yours.

I'm afraid it has all the appearance of a slick, canned, oil industry "gee whiz!" PR production. Thankfully, this fossil fuel article was gratifyingly offset by the PV article (page 84 & 85) and its record efficiency! You must realise this is the way of the future.

I doubt this letter will be published but that's irrelevant. I urge SILICON CHIP to get back on the "golden path" towards a solar/wind/low CO_2 future, and publish more articles thereof.

Mike Barrett,
Perth, WA.

Support for Micromite programming tutorials

Following Cliff King's letter in the July 2016 issue on page 6, my answer is an emphatic "yes". I regularly use Geoff Graham's Backshed forum and the people who frequent it are awe-inspiring for their knowledge.

I often see references to the Micromite Programming Manual. In my case, I need a manual to understand the manual. It assumes a level of expertise that newbies like myself do not have. Hence my purchase of the BackPack kit, to experiment with.

David Benzie,
Connolly, WA. SC

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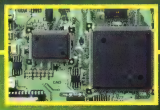

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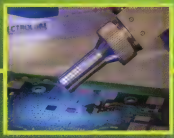

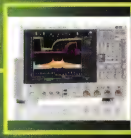

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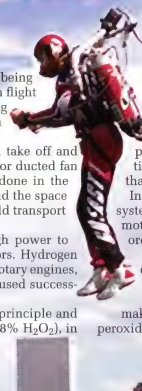
Ever since the legend of Icarus man has dreamed of being able to fly. Ma has since flown in various ways, such as kites that could carry men in China in the 5th century, hot air balloons in France in 1783 and we have been flying in heavier-than-air machines for more than a century. But the ultimate dream is to fly with the smallest possible machine that can lift a human into the air. In this article we look at machines which can – or at least perhaps have the potential to – do this.

Personal Flight Vehicles

by Dr David Maddison



Personal flight vehicles are defined as being designed to lift one or two people with flight equipment on their backs or standing or sitting on such equipment but not in an enclosure such as an aircraft cockpit.

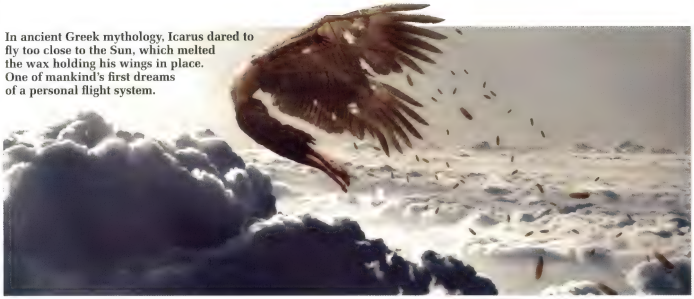
Such vehicles are mostly VTOL; vertical take off and landing, based on jet engines, rocket packs or ducted fan systems. Early work on rocket packs was done in the late 50s and early 60s for the US military and the space program where it was thought that they could transport astronauts over the lunar surface.

Personal flight vehicles require very high power to weight ratios and thus very powerful motors. Hydrogen peroxide, ducted fans with reciprocating or rotary engines, turbojet and turbofan motors have all been used successfully.

A hydrogen peroxide motor is simple in principle and uses "high test" hydrogen peroxide (85 to 98% H_2O_2), in contrast to medicinal hydrogen peroxid bought at the chemist which is 3%, food grade which is 30%. When the h drogen peroxide fuel is bought into conta with a catalyst such as silver, it violently decon poses into steam and oxygen and expands by 500 times. The resulting gas is directed through nozzle that generate thrust.

In one particular application of a personal flig system, which we will discuss later, hydrogen peroxid motors were used at the tips of a helicopter rotor order to cause it to rotate.

There are many YouTube videos and website concerned with experimenters making their ow high test peroxide fuels (since they are almo unavailable as only a few specialist compani make the fuel). Be warned: concentrated hydroge peroxide is an extremely hazardous substance and shoul



In ancient Greek mythology, Icarus dared to fly too close to the Sun, which melted the wax holding his wings in place. One of mankind's first dreams of a personal flight system.

only be experimented with if you know what you are doing.

Ducted fan propulsion systems involve a "fan" or propeller mounted in a duct or shroud. Typically the fan has more blades and is of smaller diameter than an unducted rotor.

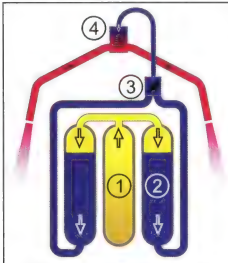
The smaller diameter fan can spin at a much higher rate than an unshrouded propeller because of the limit set by the tip speed which must be less than the speed of sound since performance drops dramatically when the tip speed approaches that limit.

So ducted fans have the advantage of compact size, relatively low noise, high efficiency at low speeds and high thrust, the ability (with appropriate mounting) of thrust vectoring and safety, as the shroud protects people and objects from coming into contact with the fan. Typical ducted fans are powered by a reciprocating engine.

A turbojet is a jet engine in which incoming air is compressed by compressor blades after which it enters a combustion chamber, where fuel is added and burned, causing the production of hot, high pressure gas. This gas then enters the turbine and expands, causing it to rotate and drive the compressor blades. After the turbine, the gas enters the tapering exhaust or "propelling nozzle" in which gas velocity is increased while pressure is decreased (according to the Venturi effect). The high speed exhaust generates thrust which propels the engine.

A turbofan is a variation of the turbo-jet engine which has large fan blades at the front of the engine that exceed the diameter of the gas turbine at the core of the engine. The large fan causes a proportion of air to bypass the engine core and the bypass air provides a proportion of the thrust.

Turbofan engines are more efficient than turbojet engines and are widely used on commercial jet aircraft. One potential disadvantage is that they are larger than a turbojet that creates the same thrust.



Operation of a hydrogen peroxide rocket motor as used in all existing rocket packs. 1) Compressed nitrogen at 4MPa or 580psi. 2) high test hydrogen peroxide 3) regulator valve 4) catalyst. The compressed nitrogen forces peroxide through the regulator valve which is controlled by the pilot and then into contact with the catalyst which causes the decomposition of the hydrogen peroxide and a volume expansion of 5000 times after which it is ejected at supersonic speed via the exhaust nozzles to create thrust.

Source: Dart evader derivative work: Malyszkz (Rocket_Belt_Propulsion.PNG), Creative Commons license.

Personal Flying Systems from the past

The Hiller Flying platform was developed in the 1950s by Hiller Aircraft as part of a US Army and US Navy program to develop a flying platform that could be flown with minimal training by the user. It utilised contra-rotating ducted fans powered by two Nelson H-56 30kW piston engines. The pilot controlled it by simply leaning in the direction he wanted to go. Several variants of the model were made and 1031-A-1 model was first flown in 1957 (see photos overleaf).

It weighed 168kg empty and could carry an 84kg payload (pilot plus fuel), with a top speed of 26km/h and maximum service height of 10m. Its flight time duration is not known.

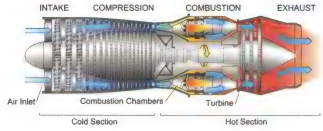
The aircraft was quite stable and could not tumble. If the pilot leaned over too far, the aircraft would tend to return to the vertical.

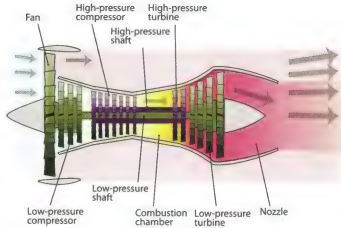
A video of the flying platform can be seen at "*Hiller Flying Platform*" https://youtu.be/W3FS3D1rCos.

The Pin-wheel helicopter

The Pin-wheel helicopter was built as part of a US military contract in 1954 and was powered by hydrogen peroxide rocket motors at the tips of the rotor blades. It was invented by Gilbert W. Magill and was intended to be folded up and stored in a small container. Since the rotor blades were propelled at their tips, there was no torque reaction to overcome and therefore no tail rotor was necessary.

It had surprisingly good performance, with a top speed of over 160km/h, a ceiling of around 15000 feet and a range of 32km on 20 litres of 90% hydrogen peroxide fuel.





These two diagrams show the difference between the turbojet engine (above) and the turbofan engine (right). *Image source: (above) Jeff Dahl; (right) K Aainsqatsi – both Creative Commons licence.*

You can read more about this project, from before this aircraft first flew, in Flying magazine of February 1952 at https://books.google.com.au/books?id=3XUK_52VvmYC

Also see Popular Science of January 1952 https://books.google.com.au/books?id=ryEDAAAAMBAJ&pg=PA89

A video of this device flying can be seen at "*One-Man Helicopter (1957)*" https://youtu.be/GpPHT2UvplA

The Bell Rocket Belt

The Bell Rocket Belt is perhaps the most well known of all personal flight systems, having been used in TV serials such as *Lost in Space* and the James Bond movie *Thunderball* as well as in numerous public displays such as the opening of the 1984 Los Angeles Olympics.

The Bell Rocket Belt started to be developed in the mid 1950s for the US Army and was demonstrated to the Army in 1961 although they were not impressed with the short flight time of 21 seconds. It too used a hydrogen peroxide propulsion system. Control is conducted by moving the rocket nozzles and also tilting the entire pack to fly sideways as well as the pilot moving their body.

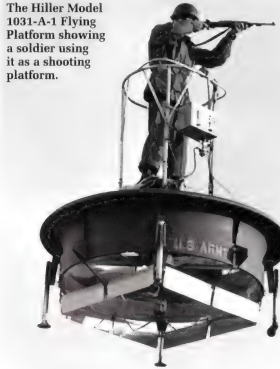
As the pilot will fall out of the sky when the fuel runs out at 21 seconds, it is vitally important to know when to land. There is a timer that beeps every second until the 15 second mark is reached and then sounds continuously telling the pilot to land.

The thrust developed was 136kg and it could fly at up to 55km/h. The rocket belt weighed 57kg and it carried 19 litres of fuel.

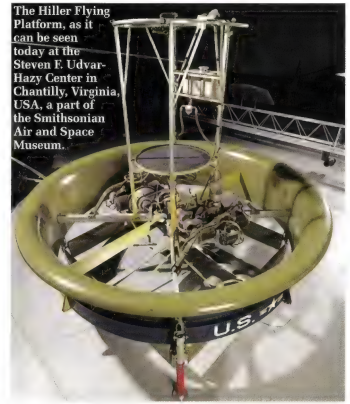
Wendell Moore was the inventor and today all existing rocket packs are based on his design. An attempt by some entrepreneurs to build an improved version of this rocket belt in 1992, called the RB2000, using more modern lightweight alloys and other materials resulted in a pack that had only slightly better performance than the original with a flight duration of 30 seconds and a fuel capacity of 23 litres.

Bell Pogo

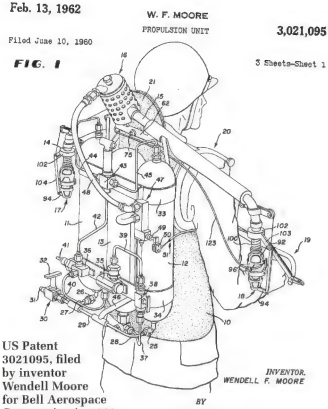
One version of the Bell Pogo was like a two-person version of the Bell Rocket Belt. NASA had an interest in it



The Hiller Model 1031-A-1 Flying Platform showing a soldier using it as a shooting platform.



The Hiller Flying Platform, as it can be seen today at the Steven F. Udvar-Hazy Center in Chantilly, Virginia, USA, a part of the Smithsonian Air and Space Museum.


Feb. 13, 1962
W. F. MOORE
PROPULSION UNIT
3,021,095
Filed June 10, 1960
FIG. 1
3 Sheets-Sheet 1
INVENTOR.
WENDELL F. MOORE
BY
ATTORNEYS

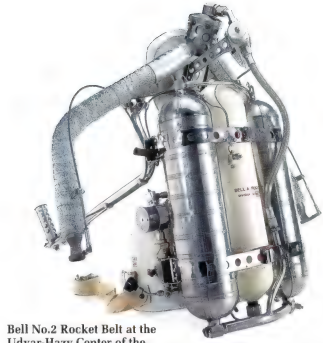
US Patent 3021095, filed by inventor Wendell Moore for Bell Aerospace Corporation in 1960, entitled "Propulsion unit".

as a lunar exploration vehicle and the US Army had an interest in it as a vehicle to cross ravines. NASA decided the risk of a crash was too high and the Army decided it was too complicated to use without a lot of training. The other version of the POGO was designed for one person.

For a video of both the one and two person Bell POGOs in operation see http://videos.howstuffworks.com/discovery/33674-strange-planes-the-bell-pogo-video.htm

de Lackner HZ-1 Aerocycle Flying Platform

The de Lackner Aerocycle was designed as a one man reconnaissance platform for the US Army. The designer, Charles Zimmerman, proposed a platform beneath which



Bell No.2 Rocket Belt at the Udvar-Hazy Center of the Smithsonian National Air and Space Museum in Chantilly, Virginia, USA. The centre tank contains pressurised nitrogen which forces the hydrogen peroxide in the side tanks into the catalyst structure on top where it rapidly decomposes into steam and oxygen, whereupon it expands in volume by 5000 times and is ejected out of the nozzles on the side.

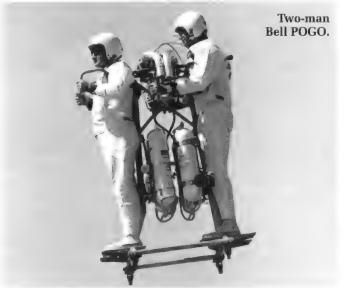
helicopter-like rotors were mounted. Control was to be effected by the pilot shifting their body weight, so-called kinesthetic control.

The aircraft first flew on the 22nd November 1954 and 12 were built for the US Army and 160 test flights were conducted.

It had an empty weight of 78kg, a maximum weight of 206kg and a fuel capacity of 3.8 litres. It was powered by one Mercury 20H 30kW marine engine and had a maximum speed of 121km/h and cruise speed of 89km/h.

Its range was 24km and maximum flight time was 45 minutes with a service ceiling of 5000 feet.

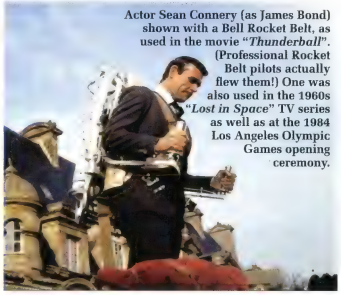
It was intended to carry up to 54kg of cargo or an extra



Two-man Bell POGO.

The de Lackner HZ-1 Aerocycle was available in both land-based and (as seen here) amphibious versions.

The Bell Jet Flying Belt, the world's first jet-engine powered jet pack.



Actor Sean Connery (as James Bond) shown with a Bell Rocket Belt, as used in the movie "*Thunderball*". (Professional Rocket Belt pilots actually flew them!) One was also used in the 1960s "*Lost in Space*" TV series as well as at the 1984 Los Angeles Olympic Games opening ceremony.

19l fuel tank to extend its range from 24km to 80km.

The aircraft was meant to be easy to fly and non-pilots were meant to be able to operate it with only 20 minutes of instruction but it was soon determined that it was not easy to fly and only a trained pilot could operate it.

Two accidents were caused by the 4.6m diameter counter rotating blades striking and disintegrating. The conditions under which the blades would strike each other were never able to be determined and these crashes and the fact that only trained pilots could fly it caused the cessation of the program.

A video of the Aerocycle flying can be seem at "*One-Man Amphibious 'Copter*"; https://youtu.be/1oYS_5SgU_0.

Bell Jet Flying Belt

The world's first jet pack was the Bell Aerosystems Jet Flying Belt, built for the US Military. It was designed to overcome the limitations of the hydrogen peroxide fuelled Bell Rocket Belt with its sub-30 second flight times. A new miniature jet engine, called the WR19 inside the company (F107 outside the company), needed to be developed for this project by Williams Research Corporation (now known as Williams International) as there were no small jet engines available at the time.

This engine was later used in cruise missiles such as the Tomahawk. As used in the Flying Belt, it weighed 27kg and produced 195kg of thrust while consuming about 136kg of Jet-A fuel per hour. The flight time was about 20 to 25 minutes at speeds of up to 135km/h. The engine was classified as a military secret at the time and never used in non-military aircraft. Its performance was such that it produced the same power as small civilian aircraft at the time (1965) but at one twentieth of the size. Even today, the power to weight ratio of this engine is hard to match.

The engine was mounted vertically on the Flying Belt, with the air inlet at the bottom and the exhaust at the top and then into nozzles on either side. These could be tilted forwards, backwards or sideways by the pilot to control motion, just like in the Bell Rocket Belt.

The Jet Belt first flew on 7th April 1969 but on 29th May 1969, Wendell Moore, who invented this and the Rocket Belt, died at age 51 and work on the project stopped forever. Who knows where this work would have gone if he had not prematurely passed away?

With Wendell Moore's death, the project eventually did not have the support of the military as the weight of the device was too great, making landings hazardous for the pilot and the maintenance requirements of the engine were too much, not to mention the hazard to the pilot of an uncontained turbine blade failure. At this time, helicopters had also developed into very effective military air vehicles for transporting soldiers.

A video of the operation of this device can be see at: "*Jet engine Jet pack : World's first Gas-Turbine backpack. The Bell WR19 Jetbelt*" https://youtu.be/DpJxzswUDD0

Williams X-Jet

The Williams X-Jet was in a way a development of the Bell Flying Belt. Engineers tried to work out how to extend the flying time beyond the 20-25 minutes of the Flying Belt. This required carrying more fuel. They were inspired by the Hiller flying platform (see above) which the pilot stood on. Such a platform would enable the carrying of more fuel than could be carried on the pilot's back.

The X-Jet had a modified Williams F107 engine with 258kg thrust, somewhat more than the same engine used in the Flying Belt. The X-Jet's empty weight was 182kg and fully loaded it was 250kg. It had a maximum speed of 96km/h, a service ceiling of 10,000 feet and endurance of 30-45 minutes, around twice as long as the Jet Belt.

Flight control was by leaning in the direction of desired travel and by thrust control. It worked successfully and was demonstrated to the US Army in the 1980s but no suitable military application could be found that could

The Williams X-Jet, nicknamed "the flying pulpit".

not be achieved with helicopters.

Videos of the Williams X-Jet can be seen as follows: "*The WASP (Williams Aerial Systems Platform)*" https://youtu.be/XJARrc40imk. This video is a video of a display screen at the Boeing Museum of Flight in Seattle, Washington, USA: "*WILLIAMS X-JET*" https://youtu.be/wLsqyphVERA Also see "*Your Personal Flying Machine X Jet WASP!!*" https://youtu.be/27HaGvHzbgQ

Coaxial Helicopter

The Gyrodyne XRON model was a small helicopter built in the USA in 1960. It was powered by a tiny 41kW Solar Turbines model YT-62-S turboshaft engine running on kerosene.

This aircraft was originally developed for the US Navy and later the US Marine Corps. One use envisaged was to drop this aircraft to an airman downed behind enemy lines to facilitate their escape. It was also developed into an unmanned drone. It won the "most manoeuvrable helicopter" prize at the Paris Air Show in 1961.

For a silent video of military qualification trials of this aircraft see "*Gyrodyne disposable XRON military qualification flight auto-rotation*" https://youtu.be/ogIS_VbORbc

There are also other videos of different variants of this aircraft.

An Australian registered Gyrodyne XRON one man, turboshaft-powered open cockpit helicopter.

Mythbusters' Attempt to Build a Jet Pack

In series 3 episode 8 of *Mythbusters*, they set about building a jet pack with plans obtained off the internet. They have an extremely well equipped workshop and are highly experienced and capable machine builders but they could not get the device made from these plans to fly.

Of course, as shown in this article, jet packs or personal flight vehicles as we refer to them are possible but all the devices that work have taken very large amounts of money, time and resources to get to a flying state.

The episode of *Mythbusters* where they try to build the device can be viewed at "*Mythbusters S03E08 Jet Pack*" https://youtu.be/h8zIfkMp08U

Myth: BUSTED!

Gluhareff Helicopters MEG-1X and MEG-2X

In 1952 Eugene Gluhareff created a company to build "backpack" helicopters powered by his pressure jet engine. The MEG-1X of circa 1957 weighed less than 31kg and had a single rotor blade with a tip-mounted pressure jet motor and counterweight. Maximum take-off weight was 104kg and maximum speed was 88km/h with a hover ceiling of 4900 feet. Flight endurance was 14-18 minutes.

The US Air force was impressed with the MEG-1X and asked Gluhareff to build another model, the MEG-2X, which had two blades and also a MEG-3X. These aircraft were not commercially produced and were perhaps the smallest helicopters ever built. It is understood that they only made tethered flights.

The pressure jet engine is extremely simple with no moving parts and is somewhat a akin to a pulse jet engine. Said to be "sonically tuned", it relies on precise control of sound waves in the combustion chamber. For further information see https://en.wikipedia.org/wiki/Gluhareff_Pressure_Jet

Kits are available to build a pressure jet engine.

For a video of this aircraft see "*One man Backpack helicopter Powered by G8-2 Pressure Jet Engine invented by Eugene Gluhareff 1956*" https://youtu.be/s0DY4Qe14A4

Trek Aerospace EFV-4A

The Trek Aerospace Exoskeleton Flying Vehicle (EFV) was first tested in 2003 and has a unique design with two counter-rotating 1-metre overhead ducted fans driven by an 88kW rotary motor.

Gluhareff MEG-1X backpack helicopter in a tethered flight test.

The Trek Aerospace EFV-4A.

The aircraft is controlled via a fly-by-wire system and each duct can be tilted individually. It has a top speed of 180km/h and range of 295km with a 46 litre tank. Its dry weight is 170kg and its maximum payload is 162kg. Maximum take off weight fully fuelled is 378kg.

Development of this vehicle and others based upon it seems to have ceased and Trek Aerospace now provides services related to ducted fan technology.

A video of the EFV in operation can be seen at *"Trek Exoskeleton Flying Vehicle, Personal JetPack"* https://youtu.be/KUs8riw9Afo

Personal flight vehicles under development

We will now look at some personal flight vehicles that are currently in existence or under development, such as the Jetpack Aviation JB-9 and JB-10.

Jetpack Aviation is a company run by Australian entrepreneur David Mayman and American Bill Suitor, based in California. They have recently developed and flown the JB-9 JetPack, which it and its predecessors have been under development for over 40 years. The JB-9 uses turbojet engines chosen for their compact size and lighter weight in comparison with turbofan engines, even though they have higher fuel consumption and higher exhaust temperatures.

Battery technology is important with a jet engine pack as the current drain during engine start up can be up to 50A and ongoing current is up to 15A.

The JB-9 carries about 38 litres of kerosene which is burned at the rate of about 3.8 litres per minute for around a ten-minute flight time, with an electronically limited speed of 100km/h. A JB-10 model with a top speed of 200km/h is under development

On 3rd November 2015 Jetpack Aviation flew the JB-9 around the Statue of Liberty in New York (see video).

Under further development are auto-stability systems and a parachute system that will automatically deploy. The developers are discussing the possibility of JetPack racing as a competitive sport. Also under development are improvements to engines and engine management systems, a four engine version and a flight simulator for training. Longer term plans include a fully stabilised version and the possibility of turbofan engines instead of turbojets.

Videos to watch: *"JetPack Aviation JB-9 JETPACK"* https://youtu.be/f3AwBSwFV2I; *"JB-9 JetPack Flight (Jet engine audio)"* https://youtu.be/QhnXxJs0GpE

The Martin Jetpack

The Martin Aircraft Company of New Zealand is developing a personal "Jetpack" that seems to have every possibility of becoming the world's first mass-produced system and it is under final test right now. Note that even though it is called a "Jetpack" it is powered by two ducted fans.

The Jetpack is not wearable like, for example, the Jetpack Aviation machine but has its own landing skids and the pilot stands within the machine.

It uses a custom-designed 1.2-litre 2-stroke V4 156kW engine weighing 48kg. Standard automotive gasoline is used, in a 45-litre tank. Flight duration is 30 minutes and the cruise speed is 30 knots or 56km/h. It uses "fly by wire" with no direct connection between the control surfaces and pilot stick. It has a range of 30-50km, depending upon environmental conditions, with an operational ceiling of 3000 feet. Its weight is 200kg empty.

Flying the Jetpack Aviation JB-9.

The Martin Jetpack is designed for ease of flight; if the pilot lets go of the controls it will simply hover in place.

View of the Martin Jetpack from above showing arrangement of the ducted fans.

Naturally, with an aircraft of this nature if there is an engine failure it will simply fall out of the sky, so it incorporates a ballistic parachute to arrest any fall, even from a very low altitude of six metres (see test of parachute in first video).

Deliveries are expected to start in the second half of 2016. Its initial applications will be for police, fire services, defence and emergency response organisations but it also has potential uses in the recreational market and in its unmanned remote control version, can deliver payloads of up to 120kg, unlike a quadcopter which might be restricted to a few kilograms.

It is capable of operating in a "mule train" mode in which one unit is piloted and up to five other unmanned units are electronically linked to the first one, to follow it and land.

The Martin Jetpack was Time magazine's top 50 inventions in 2010.

There is a free App available for either iOS or Android called "Martin Jetpack" that provides an augmented reality simulation and also allows you to watch videos of the Jetpack and review technical data.

Videos to watch:

"Martin Jetpack 5000 feet flight – highlights" https://youtu.be/SHPedpE70Es

"P12 Test Flight April 2014"; https://youtu.be/LDp1XztObUQ

"World's first commercial jetpack set for 2016 launch"; https://youtu.be/rvmuDQjxKxg

"Martin Jetpack Flight Demonstration 6 December 2015 Shenzhen, China"; *"Martin Jetpack Concept of Operations"* https://youtu.be/blg2LfXXqdk

Jet Pack International

Jet Pack International (www.jetpackinternational.com), based in Colorado, manufactures hydrogen peroxide fuelled rocket packs of the Bell design and puts on spectacular public shows. They offer the H202 model with a flight time of 23 seconds, a maximum distance of 402 metres and a fuel capacity of 16 litres. They also offer the H202-A with a flight time of 33 seconds, maximum distance of 762 metres and a fuel capacity of 20 litres. Their new unit code named "Falcon" is under development but no details have been released.

Hoverbike

Hoverbike (www.hover-bike.com/MA/), based in the UK, is the brainchild of Chris Malloy, of New Zealand, who started his project in his garage in Sydney. It is described as a flying motorcycle and has the approximate configuration of a quadcopter although the front and rear blade pairs overlap each other. It is intended to be flown manned or unmanned.

It started out with a two-blade design which was found to be too expensive and complicated to control, with an otherwise elegant design. Compare that with the home made hoverbike of Colin Furze, described elsewhere who also had control problems with a two blade design. Hoverbike is now concentrating on the four blade design.

Hoverbike indicate they have had extensive interest in the product from the military and other organisations. Hoverbike is relying upon crowd funding and has so far raised $89,210 of a required $1.1 million (at time of going to press). A lucky donor will win a Hoverbike if the project is successful.

The Hoverbike will use a flat twin 4-stroke 1.17-litre 80kW engine and 30 or 60 litres of fuel, depending upon whether secondary tanks are fitted. It will have a fuel burn of 30l/hr, a dry weight of 105kg, a maximum take off weight of more than 270kg and a total thrust of greater than 295kg, with an estimated range of 148km on the primary 30 litre tank and an estimated maximum hover altitude of around 10,000ft.

Aero-X Hoverbike

Aerofex (http://aerofex.com), based in California, has had the Aero-X Hoverbike concept in development since 2008. It will be able to fly 3 metres off the ground at up to 72km/h carrying two people or a load of up to 140kg. Its flight duration on one tank of fuel is 1.25 hours. It is 4.5m long, 2.1m wide, 1.25m tall and has a dry weight of 356kg.

Aero-X hoverbike.

Colin Furze's home-made hoverbike.

It runs on automotive gasoline with a 3-rotor rotary engine. Cost is US$85,000.

For a video of the Aero-X, see *"Off-Road Hover Bike Will Be Available in 2017"* https://youtu.be/uwxaZ9KCdcE

Homemade hoverbike – YouTube Build

Colin Furze has built a hoverbike which can be seen in a YouTube video entitled *"Homemade Hoverbike"* at https://youtu.be/soxxPyaAT1k

Within the description of that video there are a number of links to various aspects of the build plus his other projects. Also see a Q&A on the build at www.vessel.com/videos/aHh3cE8s5

His website is at www.colinfurze.com

The hoverbike is powered by two para-glider motor units with their propellers and support frames. He says that control is very difficult and solutions to the control problem are not so easy, especially as the machine barely generates enough thrust to lift the rider so additional weight is not feasible. Nevertheless, the vehicle does work.

He notes he may build a Mark 2 version which might include a carbon fibre frame and larger propellers and motors and some ideas to make the device more stable.

Flight using a Jet Pack International jet pack.

Catalin Alexandru Duru's "Hoverboard"

Catalin Alexandru Duru invented a battery powered "hoverboard" which seems rather similar to an octocopter that any drone enthusiast might fly but obviously scaled up to be much more powerful and sophisticated. He set the Guinness Book of Records mark on 22nd May 2015 for the furthest flight by a hoverboard at 275.9m with a flight time of around 90 seconds. His company, Omni Hoverboards (http://omnihoverboards.com) is working on a next generation however no details are available on the website.

For a video, see *"Farthest flight by hoverboard - Guinness World Records"* https://youtu.be/Bfa9HrieUyQ.

Zapata Racing Flyboard Air

Zapata Racing (http://zapata-racing.com/en/) is a company that produces hydro-propulsion equipment for water sports that enable a user to launch themselves into the air with powerful water jets delivered to the user via a hose connected to a powerful pump in a floating vehicle. The user remains tethered to the vehicle via the hose so is not capable of independent flight. They took this concept to the next level with the development of an independent jet powered platform called "Flyboard".

The Flyboard has six small jet engines, four internal engines to provide lift and two mounted on the outside

Chris Malloy's Hoverbike in ground-tethered test.

to provide stability and forward motion. The four internal engines produce around 186kW each for a total of 755kW or around 1000hp total. There are on-board electronics to stabilise the device similar to what are used in a drone. The stabilisation software works by controlling the inclination of the thrust nozzle of the internal jets and the speed of the two side mounted jets.

The Flyboard is not easy to fly and its inventor, Franky Zapata, says it is impossible to fly without 50 to 100 hours experience on their water jet version of the Flyboard however they are working on a model that is easier to fly and can be used by the general public and military.

Unlike some other personal flight systems, this one has some redundancy and can fly if one of the four internal motors fails. It also has triple redundancy of the WiFi channels it uses and the stability sensors. Jet A-1 fuel is carried in a backpack worn by the pilot.

The inventor has plans to ride the Flyboard into the clouds and will carry a parachute for safety. The inventor has also fallen into the water many times during experimental flights and says that he has not been hurt doing so. The Flyboard is capable of reaching an altitude of 10,000 feet, has a top speed of 150km/h and a flight duration of ten minutes.

On the 30th April 2016, the Flyboard achieved the world record distance for a hoverboard reaching 2252.4 metres.

The Jetman

Yves Rossy, otherwise known as the Jetman, developed a rigid 2.4m span wing with four small jet engines which he attaches to his back. His body acts as the fuselage and he controls the direction of flight by moving his body.

The engines are modified Jet Cat P200s which are the largest type of model aircraft jet made by Jet Cat with a thrust of nearly 24kg each. See **www.jetcatusa.com/rc-turbines/turbine-details/p200-sx/**

To launch, Jetman dives out of a helicopter as the aircraft has no landing gear; except for his legs! When it is time to land, he releases a parachute and floats to the ground.

Jetman has flown as fast as 304km/h with his jet-powered wing and crossed the English Channel in 2008,- reaching as much as 200km/h for the 13-minute, 35km flight.

In 2009 he attempted to cross the Strait of Gibraltar but was forced down by strong winds just a few kilometres from Spain.

Fortunately, he was not hurt and he and his machine were retrieved from the ocean within ten minutes.

Record breaking (at the time) flight of hoverboard. For safety reasons this flight, and that of other similar vehicles are made over water to minimise pilot injury in the event of engine or other failure.

In 2011 he flew across the Grand Canyon and the FAA, the US Government agency responsible for aviation regulation, classified his wing and him in combination as an "aircraft".

For a video of Jetman in action see "*Yves Rossy: Fly with the Jetman*" **https://youtu.be/x2sT9KoILM**

Tecnologia Aeroespacial Mexicana

Tecnologia Aeroespacial Mexicana (**www.tecaeromex.com/ingles/indexi.html**) is a Mexican company that specialises in hydrogen peroxide rocket engines for various applications such as rocket packs, a helicopter with rocket propulsion at the blade tips (tip jet), rocket powered dragsters, rocket bikes and a rocket car.

They manufacture rocket belts to order and sell them to suitably qualified individuals, along with equipment to make high test hydrogen peroxide which is otherwise almost unobtainable.

Aerochute

Aerochute (**www.aerochute.com.au**) is an Australian company based in Melbourne that produces a powered one or two man parachute called the Aerochute. The product was discussed in the May 2015 issue of SILICON CHIP, at

Alexander Duru and his hoverboard. Essentially it is an octocopter.
Image by Daniel Petkov

Jetman in flight. Note the four small model aircraft jet engines. Flight is controlled by him moving his body. The fuel used is kerosene.

the Australian International Airshow.

The company is engaged in ongoing development, in conjunction with the Swinburne University of Technology, of an electric version of this vehicle. A remotely operated version of the vehicle has also been developed which has range of 3 hours or 180km. While it can fly unmanned, it retains its seats so that it could fly to a remote area, pick up one or two injured people and then fly back. It could also

Flyboard Air. Note the fixed boots which keep the pilot attached to the aircraft. Also visible are the two outboard jet engines. Not visible are the four internal jet engines.

Jetman's jet powered wing in a folded state for transport and also so he can get into helicopters prior to launch.

be used to pick up or deliver supplies. Another application of the remotely operated vehicle is for aerial surveys, perhaps with remote sensing or photographic equipment.

A final development of this company is a "fly by wire" control arrangement whereby the pilot guides the vehicle via a joystick rather than the traditional controls (which remain for the purpose of redundancy).

Troy Hartman

Troy Hartman (www.troyhartman.com) is an aerial stuntman who attached jet engines to his back that produced 90kg of thrust to propel himself with a paragliding wing. You can watch a video of his flight at *"The Troy Hartman Jetpack"* https://youtu.be/Yolum7_0UCA.

Jet Powered Wing Suit

Finn Visa Parviainen developed a pair of jet boots to propel his wing suit for level flight and even climb until he runs out of fuel. He then lands in the usual way of winged suit flyers, using a parachute. For a video of his flight see *"Phoenix-Fly: Wingsuit Jet Pilot"* https://vimeo.com/16632926

Airvinci

As we went to press, Canadian company Airvinci announced that their single rotor, dual-engined "backpack helicopter" was ready for a trial flight.

The brainchild of Tarek Ibrahim and developed in his suburban garage, his dream was to develop a safe, compact and affordable means of transport, even if only to miss the daily traffic jams by flying users between home and the office!

Flyboard Air in operation. *Source: Zapata Racing.*

Visa Parviainen in flight with his wing suit and jet boots.

Comparisons have been made between it and the Martin Jetpack but Airvinci claim their craft, also a ducted fan design, will have a far greater range and with two engines, will be much safer than single-engine designs.

Initially developed as a heavy-lifting drone helicopter, the Airvinci has now morphed into a full-sized, person-carrying VTOL model. This is expected to undergo trials during 2017.

Ibrahim says that the Airvinci will have multiple applications; as well as a traffic-snarl-beater, he sees it being used as a "sky taxi" to take users direct from their homes to airports for their flights, or even as a launch vehicle for skydivers, taking parachutists up to 12,500 ft and then automatically returning to their base once the occupant has jumped out!

Initially conceived as a heavy-lift drone (left), Airvinci now plan test flights for their human-carrying model (right) next year.

He also envisages a huge number of applications in search and rescue, firefighting, public utilities and so on.

Airvinci website is www.airvinci.com, where there is also a video of the Airvinci presentation made at TEDx Toronto last October.

Conclusion

A wide variety of personal flight systems have been developed over the years and continue to be developed. Safety is of paramount concern and if these systems are to become widespread for personal transportation they must be fail-safe in the event of an engine failure, either by generating lift with a wing such as the Aerochute or with a ballistic parachute as with the Martin Jetpack. SC

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- Displays graphs of power use over time
- Logged data can be downloaded to a PC

APPLIANCE ENERGY METER

Part 1 – By JIM ROWE & NICHOLAS VINEN

How much do your appliances actually cost to run? Are you getting the most bang for your buck? This new Appliance Energy Meter will tell you exactly how much they're using, how much they're costing you and the total energy consumed. It can even log the results to your computer.

This completely new design measures the mains voltage and the appliance's load current, then multiplies the two (taking into account the power factor, including any phase difference) to work out the power being used. Then it integrates this over time to determine the total energy usage in kWh (kilowatt-hours). At the same time, it multiplies the power consumption by the energy tariff that is applicable at the time (ie, peak, shoulder or off-peak) and keeps a running total of the energy cost over time.

It displays all this (and much more information) in an easy-to-understand form via its colour LCD screen.

There are no switches or knobs to operate since all control is done via that colour LCD touchscreen, which works like the touchscreen on your smartphone.

It is based on the Micromite Backpack module plus a matching 2.8-inch LCD touchscreen module (as described in the February 2016 issue of SILICON CHIP).

One obvious use for this unit is to show refrigerator or air

conditioner running costs over a set period of time, so that you can quickly determine the effect of different thermostat settings.

Alternatively, it could be used to show the difference in energy consumption between the summer months and the winter months.

If you have a solar power installation, the Appliance Energy Meter will quickly allow you to determine which appliances are the most "power hungry", so that you can adjust your energy usage patterns to suit the time of day when solar power is available.

This will maximise the benefit of your solar panels.

For example, by running your pool pump, dishwasher, washing machine or air conditioner during the day from your solar panels, your energy cost for running these appliances will essentially be zero.

That's a much better result than merely accepting the now derisory solar feed-in tariff of typically 6 cents per kilowatt-hour.

Specifications

- Measures mains voltage, appliance current and time
- Voltage resolution (rounded for display) 0.1V
- Maximum measured current ..... 20A (100A surge)
- Appliance current resolution 0.01A
- Maximum volt-amps reading 5100VA
- Maximum wattage (real power) reading 5100W
- Wattage resolution 0.1W
- Uncalibrated error ..... typically <3%
- Calibrated error ..... typically <1%
- Sampling rate ..... ~5kHz
- Timing clock accuracy ..... <10ppm
- Logging interval ..... 1, 10 or 60 seconds
- Maximum logging duration ..... 7 days (60s interval)
- Cost resolution 0.001c/kWh

Standby power

The cost of standby power is something that most people never think about. There are lots of appliances in your home that continuously consume power 24 hours a day, even when they are supposedly "switched off", especially via a remote control. These appliances include TV sets, DVD players, hifi equipment and cable and satellite TV receivers.

Then there are those devices that are powered via a plugpack supply: modems, some printers, portable CD players and battery chargers (eg, for mobile telephones) and so on. Most continue to draw power even though the device itself might be off. But how much power? This Appliance Energy Meter will tell you.

Many high-power appliances also continue to draw current when they are not being used.

These could include your microwave oven, wall oven, dishwasher, washing machine and air-conditioners.

Typically, the standby power usage for each of these appliances is about 2W but some are significantly higher.

Then there are those appliances which must always be on, otherwise there's no point having them; for example, cordless telephones, digital alarm clocks, burglar alarms and garage door openers.

Do a quick audit of your house – you may be quite surprised at how many appliances you have that are either permanently powered or operating on standby power.

By using the Appliance Energy Meter, you can quickly monitor these devices and find out which are the energy wasters and decide which can be updated or simply turned off at the wall if they don't need to run continuously.

What about those cheap power consumption meters?

Of course, we are aware that there are plenty of power

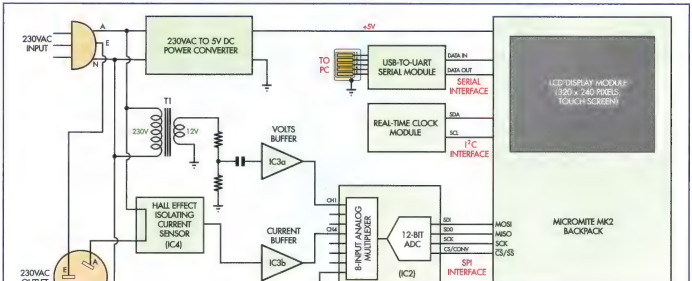


Fig.1: block diagram of the Energy Meter. T1 provides a voltage proportional to the mains while IC4's output indicates the load current. The Micromite reads both via analog-to-digital converter IC2 and displays the readings on its LCD.

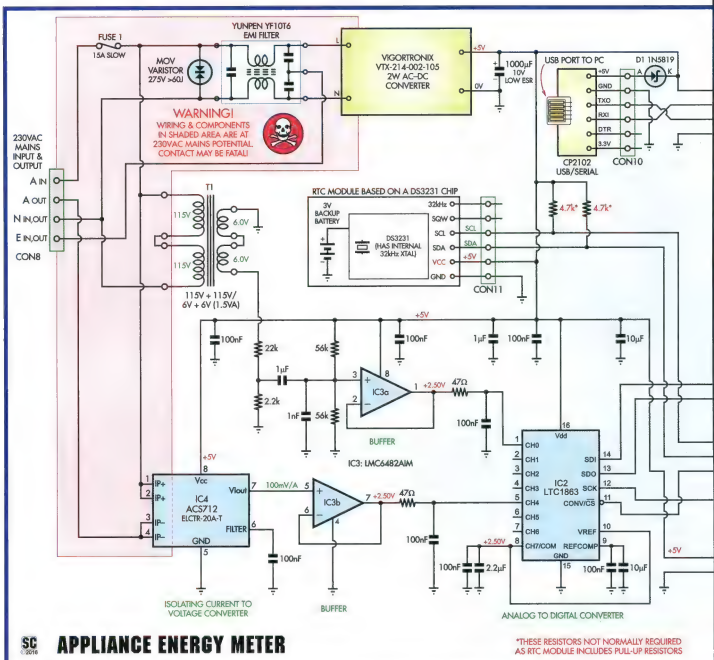


Fig.2: complete circuit of the Energy Meter. At right is the LCD BackPack with new circuitry at left. The 2.5V output at IC2's VREF (pin 10) is fed back to COM (pin 8) to allow bipolar (positive/negative) voltage readings at input pins 1 & 5.

consumption meters available on-line for around $20 to $30 which can monitor appliances. But they're not a patch on this one! Our experience is that their LCDs are often hard to read/decipher and they lack colour or any graphics capability. Nor do they have touchscreens. And we've seen two side-by-side reading quite differently on the same load!

The more expensive "wireless" models (which have a transmitter in the fuse box and a display inside) are actually quite limited in what they can show you – for example, they cannot show individual appliance power, nor can they show true energy costs (they don't know the difference between time of day tariffs so work on "worst case").

They can read current but assume a certain voltage so they can't accurately calculate power.

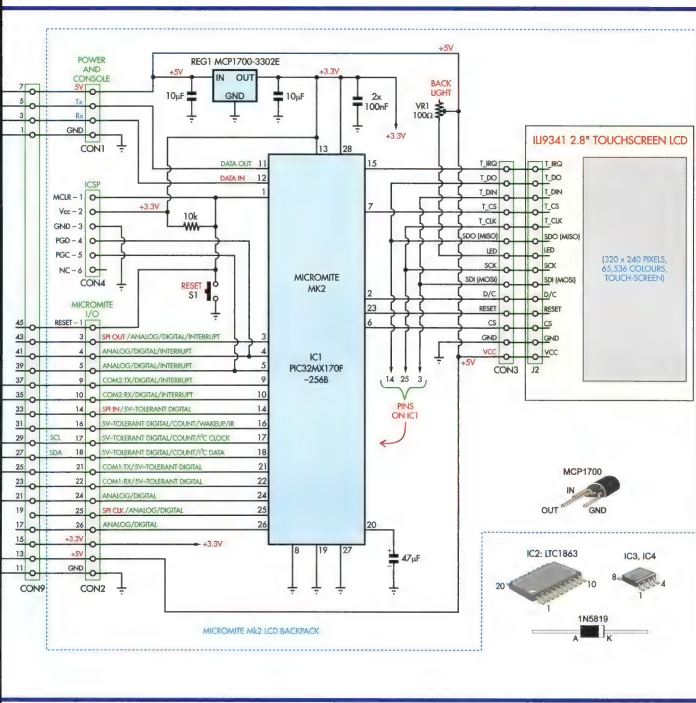
By contrast, the readings on our new Appliance Energy Meter are far more legible, with bright colours.

It also offers immediate switching between screens to show energy usage or cost over time with time-of-day tariffs always taken into account.

As well, all of this information can be displayed as graphs over time or as histograms (bargraphs) so you can quickly assess how power consumption varies as appliances cycle on and off.

Or you can see how power consumption varies over the full cycle of a washing machine or dishwasher. Say you have a washing machine that heats its own water electrically (as many European models do). Do you really need to use that hot/hot setting or will a cooler (or even cold) setting save you money?

This will tell you – and you might be in for a real surprise!



Using the Appliance Energy Meter

As shown in the photos, the new SILICON CHIP Appliance Energy Meter is housed in a compact plastic box with the touchscreen on the top panel.

It has two 250VAC 10A mains leads – one with a 3-pin plug, to supply power from the mains and the other with a 3-pin socket, to supply power to the appliance.

The unit is easy to use; simply plug it into the mains socket and plug the appliance into the output lead.

Turn the power on and it will immediately show the main screen with the following information:

- mains voltage (eg, 237VAC)
- mains current (eg, 2.25A)
- mains frequency (eg, 50Hz)
- real power (eg, 475W)
- VA (eg, 533VA)
- power factor (eg, 0.89)
- duration (elapsed time)
- running total (in kWh)
- current tariff (peak, shoulder or off-peak)
- running total cost
- current time & date

Note that if you don't have a smart meter in your home, you may only have a single tariff which applies all the time. In this case, you can leave the peak and shoulder periods blank and the unit will compute cost using just one tariff.

PCB design

Most of the circuitry for the Appliance Energy Meter is accommodated on a single, large double-sided PCB. The

Micromite BackPack and 2.8-inch touchscreen are attached to the lid and wired to the main PCB via a ribbon cable with IDC connectors.

Components on the board include an EMI filter, a 230VAC to 6V+6V transformer (T1), a 230VAC to 5V DC switch-mode converter, a precision real time clock and a USB-to-UART serial converter, for both programming and logging.

As well, there are special purpose ICs for an isolating current to voltage converter (IC4) and an analog-to-digital converter (ADC) – IC2.

How it works

As well as measuring mains voltage and appliance current, the Energy Meter does a lot of calculations and these are detailed in a separate panel.

Let's now look at the block diagram of Fig.1 which shows the overall configuration of the new Energy Meter. The heart of the Meter is the already-mentioned Micromite Mk2 BackPack with its 320 x 240 pixel colour LCD touch screen, shown at the right-hand side.

At upper left you can see the 230VAC mains input, used to provide power for the meter itself as well as for the appliance connected to the 230VAC outlet at lower left.

The two parameters that the meter needs to measure in order to work out the energy consumption of an appliance are the mains voltage and the current being drawn by the appliance.

To measure the mains voltage safely, we use a tiny step-down transformer (T1) to provide isolation. This delivers a secondary AC voltage of 12V RMS (= 33.93V peak-to-peak) when the mains voltage is 230VAC.

As this is too high for our measurement circuitry, we use a resistive voltage divider to reduce it further. Then the divided-down mains voltage signal is fed through a unity gain buffer amplifier, IC3a. The relationship between this voltage and the mains voltage is calibrated via the software.

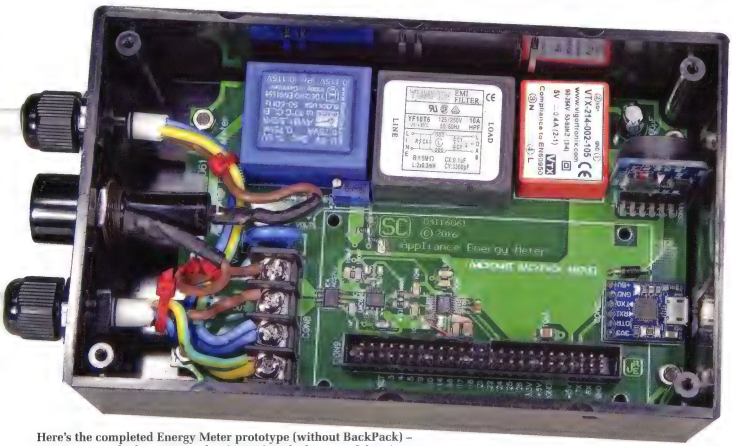
To measure the appliance current, we use an Allegro ACS712-x20A isolating linear current sensor, IC4. This provides linear current sensing over a range ±20A, with an input-output isolation of better than 2.1kV RMS or 5.9kV peak-to-peak.

The appliance current passes through a very low resistance "loop" on one side of the device, while on the other side, a linear Hall Effect circuit senses the magnetic field around the loop and provides an output voltage proportional to the instantaneous loop current. The output voltage is specified as 100mV/A, linear over a ±20A range. The output voltage from the current sensor passes through another unity gain buffer amplifier, IC3b.

The outputs of the two buffer amplifiers are connected to two inputs of the input multiplexer (selector) inside a Linear Technology LTC1863 12-bit analog-to-digital converter, IC2. The ADC then takes samples of the voltage and current signals, under the control of the Micromite processor which communicates with the ADC via an SPI (serial peripheral interface) bus.

So that describes the main measurement part of the new energy meter.

There is also the real-time clock module (just above the ADC), which connects to the Micromite via an I^2C interface and is used to provide the meter's accurate timing (important for time-of-day metering). A USB-to-UART serial module (just above the RTC module), which is connected to the Micromite via a serial interface, is used for



Here's the completed Energy Meter prototype (without BackPack) – it connects to the long IDC socket (CON9) at the bottom of the picture.

The energy meter uses the Micromite BackPack with a 2.8-inch LCD touchscreen (you can read all about it in the February 2016 issue of SILICON CHIP).

downloading the meter's firmware program from your PC and off-loading logged data for analysis.

The 230VAC to 5V DC Power Converter at the upper left corner of Fig.1 provides +5V DC power for all of the meter's circuitry, including the Micromite and its touchscreen display. Note that we did not want to use a conventional transformer, bridge rectifier and regulator circuitry to provide the 5V rail as it would have been more expensive and would have needed more space on the PCB.

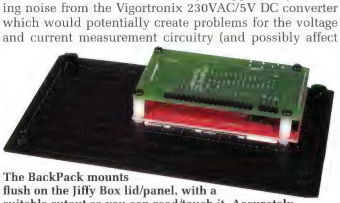
Circuit description

Now have a look at the full circuit diagram of Fig.2. Although it is two pages wide, it is laid out in a very similar way to the block diagram of Fig.1. The internals of the Micromite and its LCD touchscreen are shown on the right-hand page, while the rest of the Meter's circuitry is shown on the left-hand page.

There are a few items in the pink shaded "live" area of the circuit at far left which were not shown in Fig.1 - namely fuse F1, a MOV (metal oxide varistor) and the EMI filter module connected ahead of the 230VAC input to the VTX-214-002-105 power converter. There's also a four-way screw terminal strip (CON8) used to make the mains input and output connections, at left centre.

Fuse F1 is there to prevent damage to the Meter circuitry (and components, especially current sensor IC4) in the event of a serious overload. The MOV prevents damage to the Meter circuitry in the event of a damaging over-voltage spike on the incoming mains lines.

The EMI filter is included mainly to suppress any switching noise from the Vigortronix 230VAC/5V DC converter which would potentially create problems for the voltage and current measurement circuitry (and possibly affect



The BackPack mounts flush on the Jiffy Box lid/panel, with a suitable cutout so you can read/touch it. Accurately machined acrylic panels are available from the SILICON CHIP Online Shop to save you the trouble of cutting the hole.

Parts List – Appliance Energy Meter

1 double-sided PCB, code 04116061#, 132 x 85mm
1 UB1 jiffy box, 158 x 95 x 53mm
1 Micromite LCD BackPack kit with 2.8-inch TFT colour touchscreen*
1 real-time clock module, DS3231 based*
1 CR2016, CR2025, CR2032 or LIR2032 button cell
1 USB to UART serial converter module*
1 Block AVB 1,5/2/6 2 x 115V to 2 x 6V 1.5VA transformer (element14 2428624)
1 Vigortronix VTX-214-002-105 AC-DC switchmode power supply, 5V output at 400mA (element14 2517750)
1 Yunpen YF10T6 EMI filter, 250VAC/10A (Jaycar MC4000)
1 metal oxide varistor (MOV), 275VAC working/115J (Jaycar RN3400)
1 PCB-mounting 4-way terminal barrier, 300V/15A rating with 8.25mm spacing (CON8) (eg, Altronics P 2103)
2 SIL pin headers, 6-pin vertical (CON10, CON11)
1 50-way DIL box header, PCB mounting (CON9)
2 50-way IDC ribbon cable sockets
1 100mm length of 50-way ribbon cable
8 6mm-long M3 Nylon or polycarbonate screws
4 M3 tapped 6.3mm Nylon spacers
4 10mm-long M3 screws
4 12mm-long M3 tapped spacers
4 6mm-long M3 screws
12 M3 flat washers
1 panel-mounting 3AG fuseholder, "very safe" type (Jaycar SZ2025 or similar)
1 15A slow-blow 3AG fuse cartridge
1 230V/10A extension cord, 3m long
2 cable glands to suit 4-8mm diameter cable (Jaycar HP0724 or similar)

Semiconductors
1 LTC1863CGN#PBF 8-channel 12-bit ADC (IC2; 16-pin SSOP SMD; element14 2294556) ***or***
1 LTC1867CGN#PBF 8-channel 16-bit ADC (IC2; 16-pin SSOP SMD; element14 2115787; see text)
1 LMC6482AIM dual op amp (IC3; 8-pin SOIC; element14 1468888)
1 ACS712ELCTR-20A-T Hall effect isolating current sensor (IC4: 8-pin SOIC; element14 1329624)
1 1N5819 40V 1A Schottky diode (D1)

Capacitors
1 1000µF 10V low-ESR electrolytic
2 10µF 16V X5R SMD 3226/3216 (1210/1206 imperial)
1 2.2µF 16V X7R SMD 3216/2012 (1206/0805 imperial)
2 1µF 16V X7R SMD 3216/2012 (1206/0805 imperial)
8 100nF 16V X7R SMD 3216/2012 (1206/0805 imperial)
1 1nF 50V COG SMD 3216/2012 (1206/0805 imperial)

Resistors (All 3216/2012 [imperial 1206/0805] SMD 1%)
2 56kΩ 1 22kΩ 1 2.2kΩ 2 47Ω

* available from SILICON CHIP Online Shop – www.siliconchip.com.au/shop
\# RevG PCB, or RevF PCB with adaptor board, code 04116061, 71 x 16mm (supplied) plus 2 x 25 pin headers

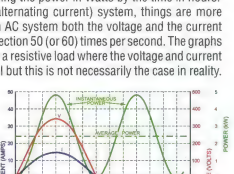
Volts, Amps, Kilowatts & Energy

In a DC (direct current) system, the power being used by a load can be worked out quite easily by measuring the voltage (V) across the load and the current (I) passing through it, and then multiplying the two figures together to get the power P in watts (W) or kilowatts (1kW = 1000W), ie, P = V x I.

Then if the load uses power of say 2kW for one hour of time, we say it has used 2kWh (kilowatt-hours) of energy, which is equivalent to 7.2MJ. In other words, the energy used is found by simply multiplying the power in Watts by the time in hours.

But in an AC (alternating current) system, things are more complicated. In an AC system both the voltage and the current are reversing in direction 50 (or 60) times per second. The graphs shown here are for a resistive load where the voltage and current are both sinusoidal but this is not necessarily the case in reality.

Now, when the load connected to the AC power is purely resistive (such as a heating element), the current that flows through it will reverse in direction at exactly the same instants as does the voltage.



A CURRENT IN PHASE WITH VOLTAGE

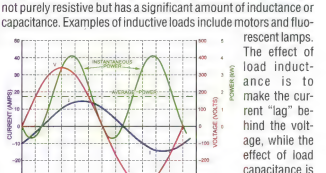
This is usually described as the current being "in phase" with the voltage, and you can see it in Fig.A.

Since the power being consumed is again found by multiplying the voltage V and the current I together, this means that the power varies instantaneously with V and I. In fact, it varies in "sine-squared" fashion, at a frequency of twice that of V and I, as shown by the solid green curve in Fig. A . Note that this varying power is always positive.

The average heating effect of this rapidly pulsing power corresponds to a steady power level very close to the midway level of the power curve, as shown by the dashed horizontal line in Fig.A.

The usual way of working out this "real power" level when V and I are in phase is by measuring the RMS (root mean square) voltage and current, and then multiplying them together. So a heater element that draws 10A RMS from a 230V RMS mains supply would be consuming 10A x 230V = 2300W or 2.3kW.

It gets even more complicated in an AC system if the load is not purely resistive but has a significant amount of inductance or capacitance. Examples of inductive loads include motors and fluorescent lamps. The effect of load inductance is to make the current "lag" behind the voltage, while the effect of load capacitance is to make the current "lead" the voltage.



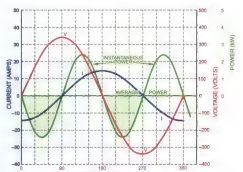
B CURRENT 45° BEHIND (LAGGING) VOLTAGE

Fig.B shows what happens when a partially inductive load causes the current to lag behind the voltage by 45°. This results in the instantaneous power curve (solid green) passing through zero and reversing in direction for part of each cycle (shaded areas). Can you guess what this means? It shows that power is actually being returned to the power company during these brief pulses. As a result, the real power being consumed by the load falls, as shown again by the dashed green line.

To work out the real power being dissipated by this kind of load, we need to multiply the RMS values of V and I together as before but then multiply this result with a variable known as the "power factor". This takes into account the phase difference between V and I, ie, the degree to which the current lags or leads the voltage. In fact it turns out that the power factor corresponds to the cosine of the phase angle Φ. In other words, real power = V x I x cos Φ.

Note that with a resistive load and no phase difference between V and I, the phase angle will be zero and the power factor equal to cos(0) = 1. That's why the real power is equal to V x I.

In closing, consider the situation shown in Fig.C, where the current is lagging behind the voltage by 90° – a full quarter cycle. As you can see the instantaneous power curve swings above the zero axis for exactly half the time, and below the zero axis for the same amount of time (shaded areas). So the "forward" and "reverse" power flows effectively cancel out, and the average power drawn by the load is zero. Needless to say the power companies are not happy with this type of load, because there is no billable power being consumed (cos(90°) = 0) – yet there is plenty of current flowing in their distribution system, so there will be energy lost in it.



C CURRENT 90° BEHIND VOLTAGE

Is that it? Well, except for simple heating appliances like incandescent lamps, radiators and ovens, real-life loads are not purely resistive, or inductive or capacitive and they do not draw sinusoidal currents. So we need to take into account the widely varying current waveform shapes from all power supplies whether linear or switchmode, all lighting such as LEDs, fluorescent, CFLs and so on. And nor is the mains voltage waveform purely sinusoidal – it usually has the peaks clipped off due to the heavy peak currents drawn by capacitive-input power supplies and fluorescent lights.

To get over that problem and to accurately measure the RMS values of the voltage and current, the ADC needs to make samples of these parameters at a minimum of 2kHz and integrate the results. This means that the accuracy of the Appliance Energy Meter will not be affected by the shape of the voltage and current waveforms, provided that the harmonics do not exceed about 1kHz.

Mind you, the fact that voltage and current sampling needs to be made virtually continuously for reasonable reading accuracy greatly increases the workload of the Micromite because while it is sampling it still needs to update the displayed readings, respond to the touchscreen commands and so on.

radio or TV reception).

Transformer T1 (at left centre) has its secondary voltage (nominally 12V) divided down to a measurable level by the voltage divider formed by the 22kΩ and 2.2kΩ resistors. Then the divider's AC output voltage (around 3.25V peak-to-peak) is coupled to the input of buffer IC3a via a 1µF capacitor, while pin 3 of IC3a is DC biased at +2.5V so the signal fed to the ADC (IC2) swings around this voltage level (which suits the ADC).

The 1nF capacitor from pin 3 of IC3a to ground and the 100nF capacitor from pin 1 of IC2 to ground provide filtering of any HF noise which may be present on the signal from T1, so that it does not affect the voltage reading accuracy.

Hall Effect current sensor IC4 has an output signal centred at +2.5V (half its supply voltage) which varies either above or below this level, by 100mV/A, depending on the direction of current flow through the sensor.

The circuitry around the LTC1863 ADC (IC2) is also quite straightforward. It contains its own high-precision voltage reference, with its output available at pin 10. We take this reference around to pin 8 of the device, which is being used as the common input for the other inputs to the device, so that the conversion result is close to zero for voltages around 2.5V. The 2.2µF and 100nF capacitors from pin 8 to ground ensure that this reference voltage is noise free.

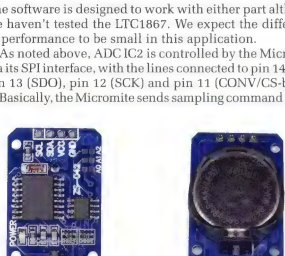
The signal from the current sensor is buffered by rail-to-rail CMOS op amp IC3b and passes through a 47Ω/100nF low-pass filter to remove any RF signals which may have been picked up.

IC4 also has a 100nF capacitor from its FILTER pin (pin 6) to ground which works with an internal 1.7kΩ resistance to reduce the output noise from the Hall effect sensor and also reduce its bandwidth to around 3kHz, to suit the sampling rate (about 5kHz) that we are using to measure the mains current.

Note that a 16-bit version of the ADC, part code LTC1867, is also available. In theory, this might provide slightly improved current resolution if substituted for the LTC1863. The software is designed to work with either part although we haven't tested the LTC1867. We expect the difference in performance to be small in this application.

As noted above, ADC IC2 is controlled by the Micromite via its SPI interface, with the lines connected to pin 14 (SDI), pin 13 (SDO), pin 12 (SCK) and pin 11 (CONV/CS-bar).

Basically, the Micromite sends sampling command words to IC2 via the SDI line, and receives the sampled data back via the SDO line. The SCK line provides the serial clock pulses for all transactions, while the CONV/CS-bar line is used to select the ADC and direct it to take each sample.



The real-time-clock module is soldered onto the PCB once the pins are bent down 90°. It is fitted with a button cell to maintain power and time in the event of disconnection.

Note that we haven't used the Micromite's hardware SPI pins for communications (pins 3, 14 & 25) but rather general purpose I/O pins 9, 10 & 24. The reason for this is that the hardware SPI pins are used to drive the TFT display and touch sensor and we need to have a dedicated SPI bus to allow continuous sampling, even while the display is in use.

The two remaining circuit sections to discuss are the RTC (real-time clock) module and the USB-serial converter module (both on the left-hand page).

The RTC module is based on a Maxim DS3231 "extremely accurate" RTC chip, which includes its own 32kHz crystal and a built-in I^2C interface. The module we've used (shown in the photos) has provision for a 3V button cell to keep time when power is removed from the meter. It also includes pull-up resistors on the I^2C SDA and SCL lines, so these are not needed on our main PCB.

The RTC module also hosts an AT24C32 4KB EEPROM (the smaller IC next to the DS3231 chip, visible in the photo at lower-left). This shares the same I^2C bus as the real-time clock.

We use this chip to store logging duration, accumulated power usage and cost information, so that if there's a black-out or brownout and the unit resets, you don't lose all the data. However, note that logged data is stored in RAM as the EEPROM is too small.

The USB-serial converter module is based on a Silicon Labs CP2102 which is a complete USB-to-serial interface. The module is about the size of a postage stamp and has a micro-USB socket on one end and a set of connections for its TTL serial port on the other.

In our Meter, the module connects to the Micromite serial port via the RXI and TXO lines, to allow the Micromite to communicate with your PC to download logged data. The same interface is used initially to program the Meter's firmware, via your PC.

Measuring power

Since the Micromite used here only has support for one hardware SPI bus, we've had to implement the second SPI bus in software, ie, by "bit banging". As there are several thousand ADC measurements per second, this is written in "C" and embedded in the Micromite BASIC code using the "CFUNCTION" statement.

This is also necessary to allow the sampling to occur even while the BASIC interpreter is busy updating the display or performing other tasks. We'll have more details on how the software works in part 2, next month.

But let's now go over how the unit measures RMS voltage, current and power. First, the CFUNCTION sets up the PIC32's internal TIMER1 at boot to call an interrupt routine (also written in C) at approximately 10kHz. This alternately samples inputs 1 & 5 of IC2, resulting in a pair of instantaneous (and more-or-less simultaneous) voltage/current readings at 5kHz.

Each time a pair of readings is completed, they are squared and accumulated into two separate 64-bit memory locations. They are also multiplied together and accumulated into a third location (for VA) and finally, if they are of the same polarity, also accumulated into a fourth location

The User Interface

Because the Energy Meter has a colour LCD touchscreen, we have put significant effort into the user interface, to maximise the unit's utility. Samples of most (but not all) available screens are shown at right. Note that these are from the prototype and some improvements and additions have been made since they were taken.

On the main screen, shown at upper-left, pressing on any element in the display takes you to a screen with more information relevant to that particular area. So for example, if you touch on the power figure, you will see a graph of power vs time and pressing on this again takes you to a power histogram.

Similarly, if you touch the time or date, you are taken to a screen where you can set the current time or date and if you touch the logging duration, you can access the logging screen which provides more information and allows you to start, stop or pause logging (and other functions, too).

In fact, the Appliance Energy Meter is so feature-packed that we have exhausted both the RAM and flash memory available in the Micromite Mk2! We had to spend significant amounts of time optimising both types of memory usage before we could fit in all the features that we felt were necessary to make the Appliance Energy Meter as useful as possible.

You may notice a trimpot in one of the photos of the assembled prototype PCB. This has been removed from the final design in favour of software calibration, which can be done via the touchscreen, with the unit completely sealed. This is much safer as it doesn't require you to insert a screwdriver into the case while mains power is applied.

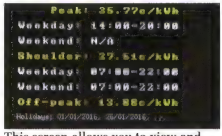
In fact, part of the calibration (to account for DC offset in both voltage and current, and noise from the current sensor) is totally automatic. The only manual calibration required is to set the voltage reading so that it matches the actual mains voltage, as determined using a multimeter (more on that next month). You can also calibrate the current readings however this is optional and can be done using a DC supply and a DMM.

The main screen, displayed at power-up, shows all the most important information at a glance: mains voltage current, real power, VA, frequency, power factor, tariff, accumulated energy and cost, current time and date and logging duration.

Touch the logging duration to access this screen with more information including the logging interval, current and maximum duration and memory usage. It also has buttons to start, stop or pause logging, export the data via USB or access calibration/diagnostics.

Touch the accumulated energy figure (in kWh) to view estimates of how much energy the load will use in one hour, one day, one week and one year. The longer you leave the unit running, the more accurate these become.

Touch the accumulated cost figure to view estimates of how much the load will cost to run for one hour, one day, one week and one year. The longer you leave the unit running, the more accurate these become.

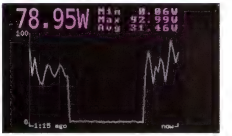


This screen allows you to view and set the three different tariffs and when they apply. Each tariff can have two different start/end times for weekdays or weekends and public holidays can be programmed in, so that the weekend rate is used on those dates.

Touch the public holidays on the screen to the left and you can enter in up to 22 different dates to indicate weekdays that should be treated as weekends for calculating the current tariff. Most Australian energy suppliers use this billing scheme.

While logging is active, data is stored in memory at one, 10 or 60 second intervals and can be plotted by touching on the parameter. Here's a sample graph of mains voltage over time.

Touching the voltage/time graph takes you to histogram mode. The selectable durations are the same as before but now you can see what proportion of the time the mains voltage spends at various different voltage levels.

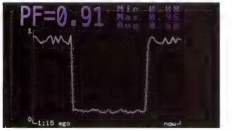


The power vs time graph is accessed by touching the power figure. All time-based graphs can be changed between one hour, one day and one week periods. If insufficient data is available, it shows that which it has accumulated so far.

All values that are logged can be displayed as either graphs or histograms. Minimum, maximum and average readings are shown at the top of each graph or histogram and indicate the range of values measured during the displayed period.

Similarly, VA (apparent power) can be graphed. While the duration can be changed, the right-most point is always the current reading. If you leave a graph on screen, once sufficient data is available, it "scrolls" right-to-left.

Histograms (such as this one for apparent power) also update automatically when they are left on the display and like the graphs, represent data for the selected duration to the present.



While minimum and maximum values are shown, note that data is averaged over the logging interval (between one second and one minute) so brief excursions to one extreme or the other may not always be reflected in these readings.

In histogram mode, 10-12 bars are normally shown and the horizontal scale is automatically determined by the lowest and highest readings over the logging period. In this case, the power factor is always low (with the load off) or high, never in between.

The vertical axis for graphs is also chosen automatically to show the whole range of values logged, hence for loads which draw more current than this, the Amps scale will be more compressed.

Finally, a histogram of load current for the last hour, which shows how the current is spread over a range from 250-400mA when the load is on and is close to zero for those times it switches off.

(for true power).

The software detects voltage zero-crossing events and when this occurs, the accumulated registers are divided by the number of readings made since the last zero crossing and the square root taken.

This yields RMS voltage, current, VA and power for the half-cycle. Multiple half-cycle readings are averaged for display and the power factor computed by dividing the real power by the apparent power.

The average power reading is multiplied by the number of mains cycles it occurs over and then divided by the detected mains frequency to compute an energy figure, which is accumulated to give total energy consumption.

Cost is computed similarly, after applying the current tariff, with the real-time clock used to determine the one to use.

The hardware: a quick preview

The Touchscreen Appliance Energy Meter is built into a UB1 jiffy box measuring 158 x 95 x 53mm.

Apart from the mains fuseholder and the two cable glands used for entry of the mains input and output cables, everything else is mounted on three small PCBs – the two used by the Micromite Backpack and its LCD touchscreen, and the main PCB we have designed for the rest of the Meter's circuitry. (The real-time clock and USB/serial converter modules are pre-assembled).

The main board is coded 04116061, and measures 132 x 85mm. All components except for those used in the Micromite LCD BackPack are mounted on its top-side.

The sole fine-pitch SMD IC is the analog-to-digital converter, IC2, as this is not available in any other package. Most of the other individual components are relatively large and easy to solder.

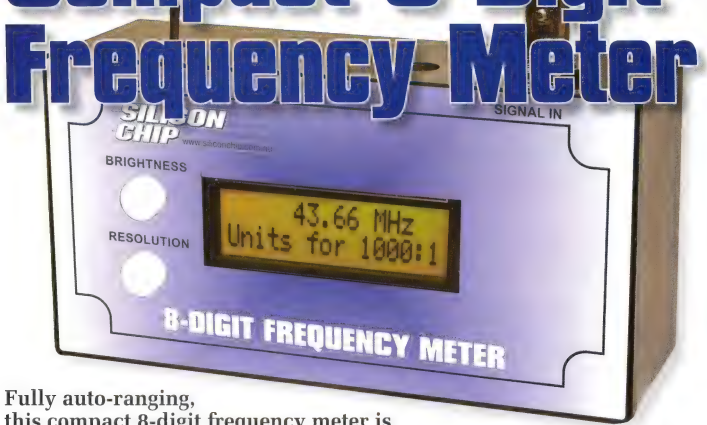
That's all we have space for this month. In the second article we'll tell you how to build it, give more details on the Micromite software, explain how to calibrate it and also describe how it's used. SC

Thanks to Geoff Graham

Our thanks to Geoff Graham, the designer of the Micromite BackPack for his assistance during the development of this project.

- **Auto-ranging**
- **Typically measures to 55MHz+**
- **Provision for external 1000:1 prescaler**

Compact 8-Digit Frequency Meter



Fully auto-ranging, this compact 8-digit frequency meter is ideal for hobbyists and technicians, for general servicing and for laboratory use. It will even cover the 6-metre amateur band. Accurate calibration can be done without any specialised equipment.

Frequency meters are used in virtually all areas of electronics and are invaluable for testing, servicing and diagnostics. Among other tasks, they are ideal for checking the frequency of oscillators, counters, transmitters and signal generators.

It is true that frequency measurements are available on many multimeters these days. However, they do not have high sensitivity nor the necessary number of digits for decent resolution at frequencies above 1kHz and most do not measure in the MHz region.

This new design is an upgrade over previous versions that used the old ECL (Emitter Coupled Logic) MC10116 differential amplifier in the front end.

Instead, we are using three 600MHz high speed op amps to do the same job (to provide increased sensitivity).

In other respects, this Mk3 version is quite similar to the previous design in that it is auto-ranging and displays the frequency in Hz, kHz or MHz with 8-digit resolution on a 2-line 16-character Liquid Crystal Display (LCD). It automatically selects the correct range and decimal place for any frequency reading.

There is provision for use with an external prescaler. If you want to measure frequencies above 55MHz you will need an external prescaler that divides the input frequency so that it is less than 50MHz.

We described a UHF 1000:1 Prescaler in the October 2006 issue. See www.siliconchip.com.au/Issue/2006/October/UHF+Prescaler+For+Frequency+Counters

By JOHN CLARKE

When set to use to such a 1000:1 prescaler, the LCD shows GHz instead of MHz, MHz instead of kHz and kHz instead of Hz.

However, this prescaler will not let you read frequencies to 55GHz+ since it has its own limitation of about 2.8GHz.

We have included a useful feature for radio control modellers, allowing the Frequency Meter to display the reading in multiples of 10kHz steps for frequencies above 36MHz, ie, the resolution is set to 10kHz.

When a standard frequency meter is used to measure crystal-locked PPM (pulse position modulation) radio control transmitters, the modulation will result in incorrect readings. Setting the resolution to 10kHz eliminates these errors.

The design is easy to build with all parts mounted on one PCB, so there is no fiddly wiring.

There are just five ICs, one being the PIC microcontroller and four surface mount ICs that are quite straightforward to solder to the PCB. Apart from the ICs, there's an LCD module, three transistors, a 3-terminal low-dropout regulator and a few resistors and capacitors.

Features

- Compact size (130 x 67 x 44mm)
- 8-digit reading (LCD)
- Automatic Hz, kHz or MHz units
- kHz, MHz and GHz units for 1000:1 external prescaler
- Three resolution modes including 10kHz rounding up
- 1MΩ input impedance
- 0.1Hz resolution up to 100Hz
- 1Hz resolution up to 16.777216MHz
- 10Hz resolution above 16.777216MHz
- Display back-light with dimming
- DC plugpack or USB supply
- Calibration without requiring a precision frequency reference

Frequency limit

Typical examples of this Frequency Meter should be OK for signals up to 55MHz or more. In fact, our prototype meter is good for 60MHz but with falling sensitivity above 50MHz. See the graph of Fig.1.

Calibration

Calibration of this Frequency Meter does not require specialised equipment.

We have devised a calibration procedure that just requires the accurate clock in a computer (synchronised via a network time server), mobile phone or any other clock or timepiece that has proven accuracy over time. The details are in a panel at the end of this article.

Resolution modes

Three resolution modes are provided: low-resolution mode with fast updates (suitable for most measurements), a high-resolution mode for greater precision when required and the already-mentioned 10kHz rounding up feature.

In low resolution mode, the resolution is 1Hz for frequencies from 1-999Hz and 10Hz for frequencies above this. The corresponding display update times are one second from 1-999Hz and 200ms from 1kHz-50MHz.

High resolution mode provides 0.1Hz resolution for readings up to 100Hz and 1Hz resolution for frequencies from 100Hz-16.77721MHz. Above this, the resolution reverts to 10Hz. The display update time is one second but is somewhat longer for frequencies below 10Hz.

0.1Hz resolution makes the unit ideal for testing loudspeakers, where the resonant frequency needs to be accurately measured.

Accuracy is 20ppm (0.002%) without calibration but it can be trimmed for even better precision.

The three resolution modes are selected by pressing the Resolution switch. When pressed, the meter displays "Low Resolution", "High Resolution" or "Rounding @>36MHz" to indicate which mode is currently selected. When the switch is released, the high or low resolution indication is not displayed. In the rounding mode, the 10kHz rounding-up only occurs above 36MHz. Below this, the standard 10Hz resolution frequency reading is displayed. Whenever the display is showing frequency rounding, the second line of

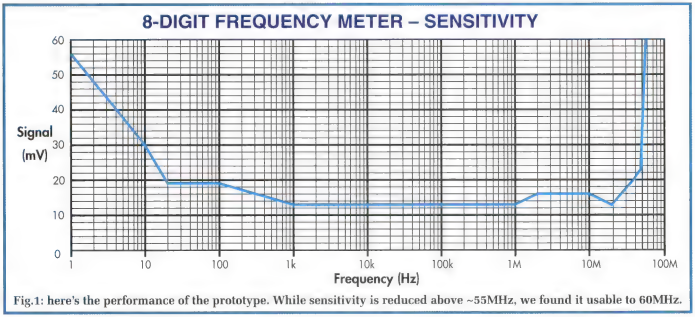


Fig.1: here's the performance of the prototype. While sensitivity is reduced above ~55MHz, we found it usable to 60MHz.

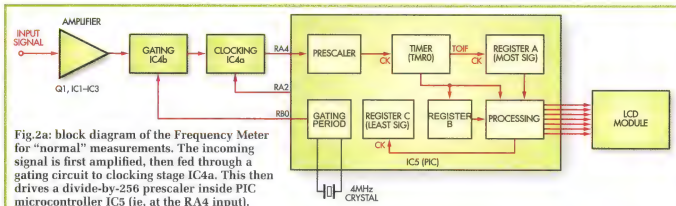


Fig.2a: block diagram of the Frequency Meter for "normal" measurements. The incoming signal is first amplified, then fed through a gating circuit to clocking stage IC4a. This then drives a divide-by-256 prescaler inside PIC microcontroller IC5 (ie, at the RA4 input).

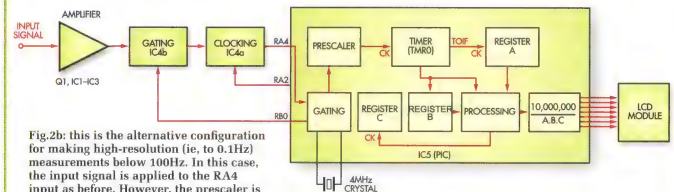


Fig.2b: this is the alternative configuration for making high-resolution (ie, to 0.1Hz) measurements below 100Hz. In this case, the input signal is applied to the RA4 input as before. However, the prescaler is no longer clocked by the RA4 input but by an internal 1MHz clock.

the display indicates this with "10kHz Rounding".

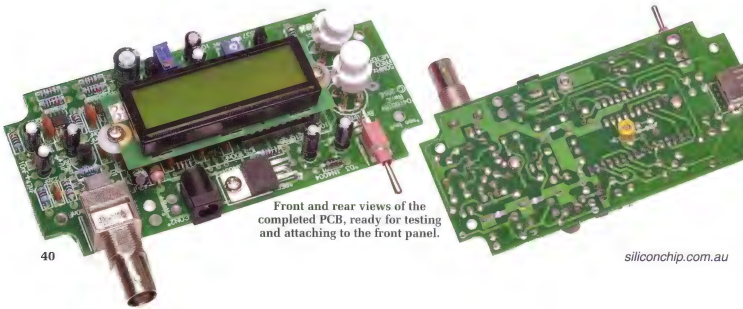
The selected resolution is stored in flash memory and is automatically restored if the frequency meter is switched off and on again. In low resolution mode, the display will show 0Hz if the frequency is below 1Hz. By contrast, in the high resolution mode, the display will initially show an "Await Signal" indication if there is no signal. If there is no signal for more than 16.6s, the display will then show "No Signal"

The 0.1Hz resolution mode for frequencies below 100Hz operates in a different manner to those measurements made at 1Hz and 10Hz resolution. Obtaining 0.1Hz resolution in a conventional frequency meter normally means measuring the test frequency over a 10s period. And that means that the update time is slightly longer than 10s. This is too long time to wait if you are adjusting a signal generator to a precise frequency.

In this frequency meter, the display update period is one second. So for normal audio frequencies, the display will update at one second intervals. We shall explain just how this is achieved shortly.

Prescaler selection

When selected, the words "Low R Prescaler" or "High R Prescaler" are shown while ever the Resolution button is held down and "Units for 1000:1" are shown on the second line of the LCD once the switch is released. 10kHz rounding is not available when using the prescaler feature.



Front and rear views of the completed PCB, ready for testing and attaching to the front panel.

Block diagrams

Fig.2a shows the general circuit arrangement of the frequency meter. It's based mainly on the microcontroller, IC5. In operation, the input signal is buffered and amplified by Q1 & IC1-IC3 and passed through gating and clocking gates (IC4) before being applied to input RA4 of IC5.

The clocking gate (IC4a) allows pulses from RA2 to toggle input RA4, to inject extra pulses while the gating stage (IC4b) is switched off. The reason that this is necessary is explained below. Note that since IC4a & IC4b have Schmitt-trigger inputs, they also serve to square up the waveform.

The RA4 input of IC5 drives an internal divide-by-256 prescaler and its output then clocks timer TMR0 which counts up to 256 before clocking 8-bit Register A, that also counts up to 256 before returning to zero.

Combining all three counters (the prescaler, TMR0 and register A) allows the circuit to count up to 24 bits, or a total of 16,777,216. By counting over a one second period, the counters can make readings up to 16.777216MHz. However, if the frequency is counted over a 100ms period, the maximum frequency count amounts to just over 167.77721MHz. This limit is somewhat restricted by the frequency limit of the internal prescaler of around 55-60MHz.

The input signal from IC3 is fed to gating stage IC4b and drives clocking stage IC4a which is controlled by IC5's RA2 output. Normally, IC4a and IC4b allow the signal to pass through to the prescaler at IC5's RA4 input. Depending on how long IC5's RB0 output is high, the signal will pass for either a 100ms period or a one second period.

During the selected period, the signal frequency is counted using the prescaler, timer TMR0 and register A, as noted above. Initially, the prescaler, the timer and register A are all cleared to zero and the RB0 output is then set high, to allow the input signal to pass through to the prescaler for the gating period.

During this period, the prescaler counts the incoming signal applied to RA4. Each time its count overflows from 255 to 0, it automatically clocks timer TMR0 by one count. Similarly, whenever the timer output overflows from 255 to 0, it sets a Timer Overflow Interrupt Flag (TOIF) which in turn clocks Register A. At the end of the gating period, IC5's RB0 output is brought low, stopping any further signal from passing through to the prescaler. The value of the count in TMR0 is now transferred to Register B.

The count in the prescaler cannot be directly read by IC5 and so we need to derive the value. This is done by first presetting register C with a count of 255 and the RA2 output is taken low to clock the prescaler. TMR0 is checked to see if its count has changed. If TMR0 hasn't changed, the prescaler is clocked again with RA2.

During this process, register C is decreased by one each time the prescaler is clocked. The process continues, with RA2 clocking the prescaler until timer TMR0 changes by one count. When this happens, it indicates that the prescaler has reached its maximum count. The value in Register C will now be the value that was in the prescaler at the end of the counting period.

The processing section within IC5 then reads the values in registers A, B and C and this is the frequency reading of the incoming signal.

Based on this information, it then decides where to place the decimal point and what units to display on the LCD. If the input signal frequency is greater than 16MHz and the

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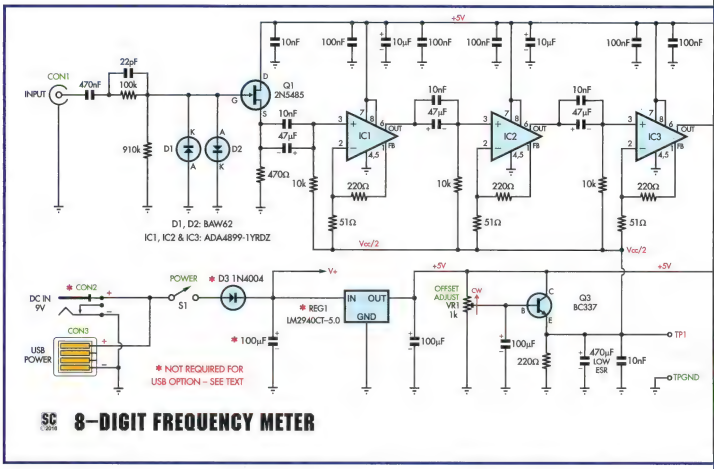


8-DIGIT FREQUENCY METER

gating period is one second, register A will initially have overflowed. In this case, the gating period is automatically changed to 100ms and the frequency is re-read.

Alternative configuration

If the high resolution mode is selected and the frequency is below 100Hz, IC5 changes its configuration to that shown in Fig.2b.

The input signal is applied to the RA4 input as before but the prescaler is no longer clocked by the RA4 input but by an internal 1MHz clock instead. RA2 and RB0 are both taken high to allow the signal to pass through to RA4. The RA4 input is now monitored for a change in state from low to high, indicating a signal at the input.

When this happens, the prescaler, TMR0 and Register A are cleared and counting the 1MHz internal clock signal begins. The overflow outputs from the prescaler and timer TMR0 are carried to register A as before.

Counting continues until the input signal goes low and then high again. That's a full cycle of the incoming waveform. At this point counting stops.

If the counting causes register A to overflow, then the display will show "No Signal" (this will happen after 16.7s if the signal does not go low and high again). Conversely, if the counting is within range, the prescaler value is determined by clocking IC4a using the RA2 output as before.

The values in Register A, B and C are now used to calculate the frequency. So if the input frequency is 1Hz, it has a one-second period and so the value in the A, B and C registers will contain a value of 1,000,000. That's because the prescaler is clocked at 1MHz over the one second period. Similarly, the count will be 100,000 for a 10Hz signal and 10,000 for a 100Hz input signal.

Finally, the value in the registers is divided into 10,000,000 and the decimal point placed immediately before the last digit. This gives a readout in Hz with 0.1Hz resolution on the LCD.

This technique cannot be used for measuring very high frequencies because the value in the counter becomes smaller as the frequency increases and so we begin to lose accuracy.

For example, at 500Hz, the counted value would be 2000 and at 500.1Hz it would be 1999. The result of the division of 1999 into 10,000,000 would be 500.2 instead of the 500.1 required. The 0.1Hz resolution has therefore been restricted to readings below 100Hz to ensure 0.1Hz accuracy.

Circuit details

Now refer to Fig.3 for the full circuit details. The input signal is AC-coupled from CON1, the BNC connector, via a 470nF capacitor to block any DC com-

The view of the assembled PCB mounted on the front panel, from the input socket/DC supply/power switch side.

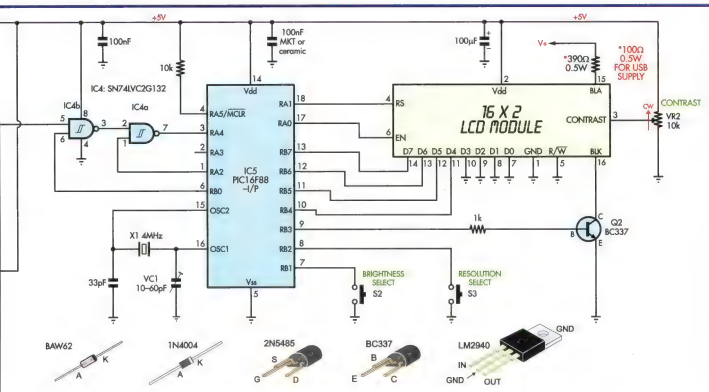


Fig.3: the input signal is fed to a JFET which provides a high input impedance (1MΩ) and then it is amplified by three cascaded wide-bandwidth op amps. The signal is then gated and "squared up" by the NAND Schmitt triggers. The PIC microprocessor then does all the counting and housekeeping and drives the LCD module.

ponent. This signal is then clipped to about 0.6V peak-to-peak by diodes D1 & D2 and any shunt current is limited by the 100kΩ series resistor.

The 22pF capacitor across the 100kΩ resistor compensates for the capacitive loading of the diodes.

From there, the signal is fed to the gate of Q1, a 2N5485 JFET. This provides a high input impedance. Q1 is self-biased using a 910kΩ resistor from its gate to ground and its 470Ω source resistor. The output at its source is about 70% of the signal level at the gate (ie, the normal signal loss in a source follower configuration).

The signal is then AC-coupled to pin 3 of amplifier stage IC1 via a 47µF electrolytic capacitor and a parallel 10nF capacitor. The 47µF capacitor is sufficiently large to allow for a low frequency response to less than one Hertz. However, this capacitor loses its effectiveness at higher frequencies due to its high internal inductance and the signal is coupled via the 10nF capacitor instead.

High frequency amplifiers

IC1, IC2 & IC3 are AD4899 high frequency op amps with a unity gain bandwidth (-3dB) of 600MHz. Each is connected as a non-inverting amplifier with a gain of 5.3, using 220Ω and 51Ω feedback resistors.

The op amps have two outputs: one labelled FB (feedback) at pin 1 and the other at pin 6. Both provide the same connection inside the op amp package, with the FB pin included to allow an optimum PCB layout for the feedback resistor.

And this view is from the opposite side – note the switch mounting method.

The three op amps are cascaded with AC-coupling via parallel 47µF and 10nF capacitors that terminate to a 10kΩ input load resistor.

Each 10kΩ resistor and the 51Ω feedback resistor connect to a Vcc/2 supply that biases each of the op amp outputs to around half supply.

Half supply rail

This half supply is required for two reasons: firstly to have the op amp outputs operate within their specified output range and secondly, so that IC3's output level will match the input voltage levels required for the following Schmitt trigger NAND gate, IC4b.

An adjustment is provided with the half supply circuitry to set the output voltage level to match best with IC4b's high and low trigger thresholds.

The half supply is made up using trimpot VR1 and transistor Q3 which is connected as an emitter follower.

The voltage at VR1's wiper is used to bias transistor Q3 and the emitter is about 0.7V lower than its base, as set by VR1. Q3's emitter is bypassed with a 470µF and 10nF capacitor to reduce the voltage ripple on the half supply, due to AC currents through

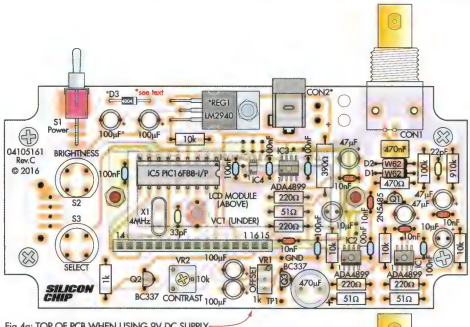
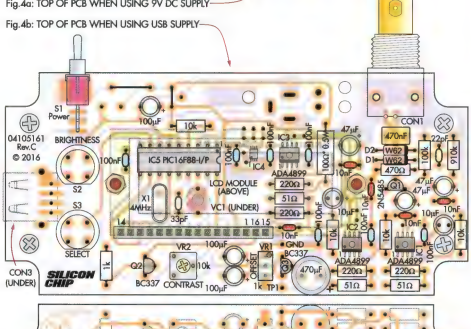


Fig.4a: TOP OF PCB WHEN USING 9V DC SUPPLY

Fig.4b: TOP OF PCB WHEN USING USB SUPPLY



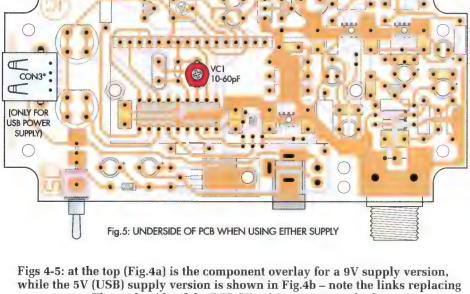


Fig.5: UNDERSIDE OF PCB WHEN USING EITHER SUPPLY

Figs 4-5: at the top (Fig.4a) is the component overlay for a 9V supply version, while the 5V (USB) supply version is shown in Fig.4b – note the links replacing components. The underside of the PCB (Fig.5) is common to both versions.

the low-value feedback resistors used with the op amps.

Signal gating

Gating and clocking of the signal from IC3 is performed by IC4 which is a dual 2-input Schmitt NAND gate package. IC4b inverts the signal applied to its pin 5 input whenever its pin 6 is held at +5V by IC5's RB0 output. When RB0 is at 0V, IC4b's pin 3 output remains high and the input signal is blocked. Essentially, the signal is allowed through to IC4a at pin 2 when RB0 is high and is blocked when RB0 is low.

IC4a's pin 1 input is normally held high by IC5's RA2 output, so that the signal from IC4b is again inverted at pin 7.

When RB0 is brought low, pin 3 of IC4b remains high and so pin 2 of IC4a is also high. RA2 can clock the RA4 input using IC4a, as when RA2 is taken high and low, this produces a low and high signal at RA4.

Driving the LCD

Microcontroller IC5's RA0 and RA1 outputs drive the control inputs (Enable and Register select) of the LCD.

The data lines of the LCD module (DB4, DB5, DB6 and DB7) are driven by the RB4, RB5, RB6 and RB7 outputs of IC5. VR2 is included to adjust the contrast of the display.

Back-lighting

Back-lighting on the LCD module is provided by two LEDs in series that connect between pin 15 and 16 of the module, with an overall voltage drop of about 3.6V. A 390Ω resistor from the raw 9V supply connects to the back-lighting LED anode and a transistor (Q2) switches the cathode side. This sets the current to about 20mA when Q2 is switched on.

If the circuit is to be powered by a USB (5V) supply, this resistor should be reduced to 100Ω 0.5W, to achieve a similar back-lighting current.

Transistor Q2 is driven via the PWM (pulse width modulation) output from pin 9 of IC5. This allows the brightness to be varied from full brightness to no backlight. Switch S2 is held down to set the brightness of the back-lighting. When the switch is not pressed, input RB1 is pulled high via internal pullup current in IC5. Similarly S3 is used to select the resolution and it too has an internal pullup.

A 4MHz crystal connected between pins 15 & 16 of IC5 provides the clock

signals for the frequency metering. The recommended crystal has low drift but a standard 4MHz crystal could be used, if accuracy is not critical. The capacitors at pins 15 & 16 provide the necessary loading for the crystal, while variable capacitor VC1 allows the clock frequency to be adjusted slightly to provide calibration.

Power supply

Power for the circuit can be from a 9V DC plugpack or a 5V USB supply. Diode D3 protects the circuit against reverse polarity when using a plugpack supply, while the low-dropout LM2940CT-5.0 regulator REG1 provides a +5V supply rail to power the circuit. The 9V variant is shown in the component overlay diagram of Fig.4a.

If you are using the USB supply option, REG1, D3, CON2 and one of the 100µF capacitors are not used. These are replaced by links, where appropriate, as shown in the component overlay of Fig.4b.

Construction

All components for the Frequency Meter (except the LCD module) are mounted on a double-sided PCB coded 04105161 and measuring 121 x 58.5mm. The PCB fits in standard plastic Jiffy box measuring 130 x 68 x 44mm.

A precision pre-cut Acrylic front panel is available from the SILICON CHIP On-line Shop that includes the holes required for the front panel switches and LCD module.

Alternatively, you *could* use the lid supplied with the Jiffy box and cut your own holes but this is at best a little messy!

If you intend running this meter from a USB supply (either a 5V plugpack or a computer USB socket), a USB socket is installed underneath the PCB, as shown in our photos (instead of the 9V supply components, as mentioned above).

However, if you intend purchasing the PCB from the SILICON CHIP on-line shop, note that after our initial stock of PCBs are sold, the replacement stock will come with pads for a micro/mini USB socket so that standard USB phone charging leads (you've probably got a few!) can be used to power the frequency meter.

Surface-mount ICs

Begin by installing the four surface mount ICs. You will need a pair of

PARTS LIST – 8-DIGIT FREQUENCY METER

1 double-sided PCB, code 04105161, 121 x 58.5mm
1 UB3 plastic case, 130 x 68 x 44mm
1 pre-drilled front panel 130 x 68mm
1 front panel label 130 x 68mm or screen printed panel
1 LCD module (Altronics Z 7013, Jaycar QP5512)
1 PCB-mount SPDT toggle switch (S1) (Altronics S 1421)
2 momentary contact pushbutton switches (S2,S3) (Altronics S 1099, Jaycar SP0723)
1 PCB mount BNC socket (CON1) (Altronics P 0527)
1 low-drift 20ppm 4MHz crystal HC49S (X1) (eg, element14 1666951)
1 18-pin DIL IC socket (for IC5)
1 16-pin DIL IC socket, cut into two 8-pin SIL IC sockets (for the LCD)
1 16-way SIL pin header (to connect to the LCD)
2 M3 tapped spacers x 9mm (LCD mounting)
4 M3 tapped spacers x 6.3mm (PCB to lid)
4 M3 tapped spacers x 12mm (PCB to lid)
2 M3 Nylon washers (LCD mounting)
4 M3 x 6mm screws (LCD mounting)
4 M3 x 12mm screws (PCB to lid)
4 M3 x 10mm countersunk screws (PCB to lid)
10 PC stakes (for S2,S3,TP1 and GND)
8 PC stake wiring sockets (Jaycar HP1260)
4 No.4 x 15mm self tapping screws (when using Acrylic front panel)

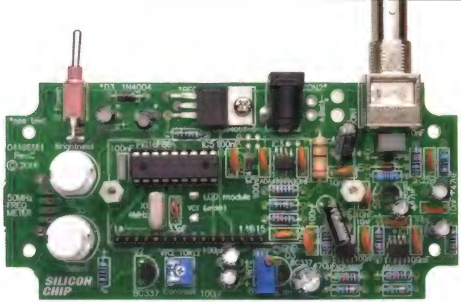
Semiconductors
3 ADA4899-1YRDZ high speed op amps (IC1-IC3; element14 1274191)
1 SN74LVC2G132DCUT dual 2-input Schmitt NAND gates (IC4; element14 1236369)
1 PIC16F88-I/P microcontroller programmed with 0410516A.hex (IC5)
1 2N5485 N-channel VHF JFET (Q1)
2 BC337 NPN transistors (Q2,Q3)
2 BAW62 diodes (D1,D2)

Capacitors
1 470µF 10V low ESR PC electrolytic
3 100µF 16V PC electrolytic
3 47µF 16V PC electrolytic
2 10µF 16V PC electrolytic
1 470nF MKT polyester
1 100nF ceramic or MKT polyester
6 100nF ceramic
5 10nF ceramic
1 33pF NP0 ceramic
1 22pF NP0 ceramic
1 10-60pF trimmer capacitor (VC1)

Resistors (1%, 0.25W)
1 910kΩ 1 100kΩ 4 10kΩ 1 1kΩ
1 470Ω 4 220Ω 3 51Ω
1 1kΩ multi-turn top adjust trimpot (VR1)
1 10kΩ miniature horizontal mount trimpot (VR2)

Power supply options
9V DC plugpack input
1 PC mount DC socket with 2.1 or 2.5mm connector pin (CON2)
1 M3 x 6mm screw and M3 nut for REG1
1 LM2940CT-5 low dropout regulator (REG1)
1 1N4004 1A diode (D3)
1 100µF 16V PC electrolytic capacitor
1 390Ω ½W 5% resistor

USB supply
1 PCB-mount USB socket (Jaycar PS0916 or element14 2112367/ 2293752; see text)
1 100Ω ½W 5% resistor



This view of the completed prototype PCB, without the LCD module in place, shows not only how the module mounts but also the components which fit underneath it. Some of these need to be laid over to accommodate the LCD module, as explained in the text.

tweezers, a fine tipped soldering iron, 0.71mm diameter solder, solder wick, flux paste plus a magnifier and bright light. Start with IC1, IC2 and IC3. Orient each IC with pin 1 positioned as shown on Fig.4. First, tack solder a corner pin to the PCB pad. Check that the IC is aligned correctly onto the PCB pads before soldering the remaining pins. Any solder bridges between the IC pins can be removed with solder wick.

IC4 is a much smaller package but the process is the same. The IC is first tack-soldered at a corner pin and carefully aligned by remelting the solder, if required. Then solder the remaining corner pins. Pins 2 connects to pin 3 so these can be soldered as a pair but make sure there are no solder bridges between any other pins.

The resistors can be installed next. Check their value against the resistor colour code table opposite (and preferably confirm with a digital multimeter) before you install each one.

Next, fit the diodes. Make sure they have correct polarity with the striped end (cathode, k) oriented as shown in the overlay diagram. D1 and D2 are BAW62 diodes and D3 can be either a 1N4004 or 1N5819. We recommend using an IC socket for IC5. Take care with orientation when installing the socket and when inserting the IC.

There are 10 PC stakes to install. These are for TP1, GND (optional) and four each for S1 and S2. The latter are so that the switches can be raised off the PCB using PCB pin sockets.

Capacitors can be installed next. The electrolytic types must be fitted with the polarity shown, with the positive (longer) lead toward the right of the PCB. There are 10µF and 47µF capacitors in the region where the LCD module will sit – these two capacitors will need to tilt over so they are not any higher than 9mm above the PCB. The 100nF capacitor just to the right of S2 and the 470nF capacitor are both MKT polyester types. The remaining are ceramic – these and the polyester types are not polarised. VC1 is mounted on the underside to allow access for adjustment.

Next, fit the 2N5485 JFET (Q1) and the two BC337 transistors (Q2 and Q3) – make sure you don't mix them up because they look almost identical.

REG1, if required (for a 9V supply) can now be installed. This mounts horizontally on the PCB with the leads bent at 90° to insert into the holes. The metal tab is secured to the PCB using an M3 x 6mm screw and M3 nut. Secure this tab before soldering the leads.

Trimpots VR1 and VR2 are next. VR1 is a 1kΩ multi-turn vertical type and may be marked as 102. This is placed with the adjusting screw towards the middle of the PCB. VR2 is 10kΩ and may be marked as 103.

Crystal X1 is mounted as shown. The recommended 3.5mm-high HC49S type will sit flush on the PCB but if you are using the standard 13.5mm crystal package (HC49U) instead, it will need to be placed horizontally on the PCB (ie, with the leads bent down 90°) so the LCD module will fit without fouling the crystal.

The LCD module mounts on the PCB via an in-line 16-way header. The socket, which is soldered to the LCD, can be cut from a dual-in-line 16-pin (DIL16) socket to give two 8-pin socket strips, which are mounted end-to-end on the underside of the LCD module (see photos).

Install the BNC socket, power switch S1 and CON2 or CON3 depending on the supply option you are using.

Switches

Switches S2 and S3 need to be mounted above the PCB so they just poke through the front panel.

They are installed by firstly inserting the PC stake sockets fully onto the PC stakes. Then the switches are placed over these sockets and the switch pins soldered to the socket ends. The switches should sit with about 26mm from the top face of the switch to the top of the PCB.

Final PCB preparation involves attaching M3 tapped standoffs to the top of the PCB to mount the LCD module and the front panel/lid.

The LCD module mounts on two 9mm standoffs with a 1mm thick Nylon washer (or use 10mm standoffs). It is secured with M3 x 6mm screws. For

The LCD module, shown here, has a 16-way header socket soldered to the underside, which mates with a 16-way header pin on the top of the PCB.

TWO METHODS FOR CALIBRATING THE FREQUENCY METER

Strictly speaking, there is no need to calibrate this frequency meter if you use the specified 20ppm crystal. At 50MHz, the error should be within ±10kHz. So your reading could be anywhere between 49.99MHz and 50.01MHz. There will also be changes in the frequency reading with temperature.

If you want better accuracy, then the Frequency Meter will need calibration. Two methods are available: one that requires a fixed frequency reference (the quickest method) or using an accurate clock.

The first method involves applying an accurate frequency reference signal (typically 10MHz) to the unit and adjusting VC1 (via a hole drilled in the back of the case) to get the right frequency reading. Typical frequency references have a frequency output derived from a GPS timebase or a temperature-controlled crystal oscillator. If you want to build your own GPS-based frequency reference, we have a suitable design. See the March-May 2007 and September 2011 issues. Previews are available at:

- www.siliconchip.com.au/Issue/2007/March/GPS-Based+Frequency+Reference%3B+Pt.1
- www.siliconchip.com.au/Issue/2007/April/GPS-Based+Frequency+Reference%3B+Pt.2
- www.siliconchip.com.au/Issue/2007/May/GPS-Based+Frequency+Reference%3A+Circuit+Modifications
- www.siliconchip.com.au/Issue/2011/September/Improving+The+GPS-Based+Frequency+Reference

Note that the reference reference frequency should be between 1MHz and 16.77MHz, allowing the meter to operate with 1Hz resolution for best precision.

Software calibration

Another method of adjustment is to use a calibration feature incorporated in the frequency meter software. This is accessed by holding the Brightness switch down as power is applied, then releasing the switch. The display will show frequency in Hz on the top line and a calibration value in parts per million (ppm) on the second line. The calibration value is initially 0ppm and can range between -50 and +50ppm. Use the Select switch to decrease the value and the Brightness switch to increase the value.

Note that you may have to press and hold a switch for up to one second before the value changes. The switch must be released and repressed to increment or decrement the value again. The one second period wait is because the frequency reading section as shown on the top line takes one second to update.

The frequency displayed is in Hz rather than the kHz and MHz units when the frequency meter is used normally. So 10MHz will be shown as 10,000,000Hz without the comma breaks.

Adjust the ppm value so the frequency reading matches the reference frequency. Positive adjustments will have the effect of lowering the frequency reading and negative values will increase it. Once set, the ppm value is stored in flash memory and will be used every time the frequency meter is switched on. Normal frequency meter operation is restored by cycling power to the unit.

Calibration with a clock

This method also involves software calibration, as described above. In theory, you could adjust VC1 when calibrating against a clock but it's too hard to make the right adjustment.

Our Frequency Meter software incorporates a real time clock function that can be set to the same time as an accurate clock. The drift in time over an extended period will allow the parts per million error to be calculated. This ppm value is then entered to correct the clock in the frequency meter.

The clock function is accessed by pressing and holding the Select switch as power is applied to the Frequency Meter. The top line on the LCD will show the time in 24 hour format, initially 00:00:00. The lower line shows "^h" and "^m" to indicate that the hours and minutes are adjustable using the Brightness and Select switches respectively. The seconds are cleared on each minutes change.

First set the hour, then the minutes and finally, press the Select switch as the reference clock roils over to the next minute.

Note that if using the clock in a computer, it should be synchronised with the same on-line time server both before setting the Frequency Meter clock and when comparing the frequency meter clock drift. Make sure there isn't a leap second within this period. Any other clock or watch can be used but it must be known to be accurate and have a seconds display.

A clock that uses the 50Hz (or 60Hz) mains frequency as its reference is not suitable since short term accuracy is not guaranteed. Typically, the clock in a smart-phone is very accurate if set to automatically synchronise with network time. Alternatively, the time may be synced to GPS signals.

A counter on the second line of the LCD shows the number of seconds that the clock has been running. This should roll over to a reading of 100,000 after about 28 hours. This is the minimum period that you should leave it running before calculating the calibration adjustment; longer is better. You cannot make frequency measurements during this time.

Now compare the clock on the Meter to your reference clock (after syncing it, if necessary) and calculate the number of seconds difference. Multiply this by 1,000,000 and divide by the number of seconds on the second line of the LCD. This is the required ppm adjustment. If the clock on the Meter is slow compared to the reference clock, the required ppm adjustment will be positive whereas if the Meter clock is fast, it will be negative.

The minimum time period required to get 1ppm accuracy is 11 days and 12 hours (11.5 days). You can check the clock at this time, when the seconds reading rolls over to 1,000,000, to make the calculation simpler, ie, the required ppm correction value is simply the number of seconds difference between the Meter clock and the reference clock.

Once you've calculated the required ppm adjustment, enter it by switching the Meter off and switching it back on while holding the Brightness switch. The adjustment procedure is described above. Then cycle the power to return the Meter to its normal measurement mode.

the lid, the mountings comprise 6.3mm and 12mm standoffs stacked together. Each 6.3mm standoff and 12mm standoff are secured with an M3 x 12mm screw to the PCB. The front panel is secured with M3 x 6mm countersunk or cheese head screws. The front panel/lid should not be attached until the PCB is installed first in the box.

Before mounting the PCB in the box, apply power and check that the display shows valid characters. Adjust VR2 for best contrast.

Check that the brightness switch works and varies the back-lighting with switch pressing. Holding the brightness switch will cause the back-light to either continue dimming or increase in brightness.

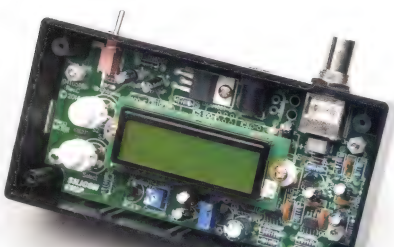
The maximum or minimum setting can be achieved by holding the switch pressed for five seconds. Each time the brightness switch is released and then pressed again, the dimming direction will change. Similarly, each press of the Resolution switch should change the display resolution to the next selection in a cyclic fashion and this includes the prescaler selections.

Offset adjustment

VR1 is adjusted so that the IC3 output swing corresponds to the input thresholds of Schmitt trigger IC4. TPGND and TP1 are provided to enable a basic setting. Adjust VR1 so TP1 is at 2.5V. Final adjustment can be made to set the signal sensitivity by applying a signal at say 100kHz and reduce the signal level until the Frequency Meter just starts to become erratic in readings. This is the sensitivity threshold.

Readjust VR1 and check if the sensitivity can be improved winding both clockwise and then anticlockwise to find the setting that gives best sensitivity. You may need to reduce the signal level as the sensitivity improves with VR1 adjustment to maintain the sensitivity threshold.

If you find that the frequency meter shows erratic values above 40MHz, a small adjustment of VR1 either clockwise to increase the offset or anticlockwise should fix this. For our prototype, a 2.69V setting at TP1 proved ideal.



Finally, here's how it mounts in the jiffy box, obviously without the lid/front panel in place. Front panel art can be downloaded from siliconchip.com.au

Mounting the PCB in the box

If you are using the pre-drilled front panel, then the only holes to drill are in the base of the box. A drilling template, which can be downloaded from www.siliconchip.com.au, shows the position of each hole on the box. Note that this does not include a hole in the base to access VC1 for trimming. This may be required; see the panel on calibration overleaf for details.

The positioning for the front panel holes and cut outs are also provided if you are doing this yourself. If you are not using the USB connector, there is no need to cut this hole out.

The front panel artwork (as seen in the lead photo) can also be downloaded and printed. To produce a rugged front panel label, print onto clear overhead projector film (using film suitable for your type of printer) as a mirror image, so the ink will be on the back of the film when it is attached. You can use white or off-white silicone sealant to do this.

Final assembly

Place the completed (and tested) PCB into the box with the spring washer already on the BNC shaft. With the PCB angled inward, the switch and BNC parts are passed through into their holes in the side of the box and the PCB is then lowered into the box and held using the BNC nut, securing this to the side panel.

Once the PCB is in the box, the front panel can be attached to the PCB using M3 x 6mm screws into the tapped spacers and then to the box, via the four outer holes.

Note that when using the Acrylic front panel instead of the original box lid, the screws supplied with the box may be too short. If so, use No.4 x 15mm self tapping screws as detailed in the parts list. SC

Resistor Colour Codes

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	910kΩ	white brown yellow brown	white brown black orange brown
❑	1	100kΩ	brown black yellow brown	red red black orange brown
❑	4	10kΩ	brown black orange brown	brown black black red brown
❑	1	1kΩ	brown black red brown	brown black black black brown
❑	1	470Ω	yellow violet brown brown	yellow violet black black brown
❑	1	390Ω*	orange white brown brown	orange white black black brown
❑	4	220Ω	red red brown brown	red red black black brown
❑	3	51Ω	green brown brown brown	green brown black black brown

(* or 100Ω for USB supply – brown black brown brown / brown black black black brown)

Capacitor Codes

470nF	0.47µF	470n	474
100nF	0.1µF	100n	104
10nF	0.01µF	10n	103
33pF	NA	33p	33
22pF	NA	22p	22

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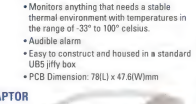

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Mid-sized board with 400 tie points.

- 83 x 55mm

DUE EARLY AUGUST

$9.95

NEW

16 KEY TOUCH KEYPAD MODULE

ARDUINO® COMPATIBLE XC-4602

A compact 16 key touch interface for your Arduino® compatible projects. Use the module as it is, or extend wires from the pads to create external touch pads.

DUE EARLY AUGUST

$89.95

NEW

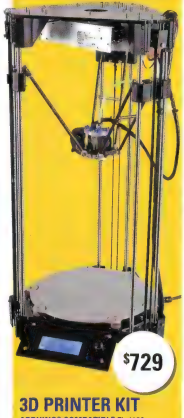
DUINOTECH EXPERIMENTS KIT

ARDUINO® COMPATIBLE XC-4287

A comprehensive kit for experimenting. Includes a duinotech Uno board, solderless breadboard, components, sensors, modules, pushbutton switches, jumper wires, LEDs, shift register IC and more.

VISIT OUR ARDUINO® PROJECTS PAGE: www.jaycar.com.au/arduino

MAKE IT, YOUR WAY!



$729

3D PRINTER KIT

ARDUINO® COMPATIBLE TL-4100

Create models, structures, samples and more with this easy to use 3D printer.

- Simple assembly
- Arduino® control
- Use either ABS or PLA filament
- Heated print bed
- 220mm (Dia.) print size
- 800(H) x 300(W) x 265(D)mm

FREE 1KG BLACK PLA FILAMENT FOR NERD PERKS CARD HOLDERS
TL-4060 *Valid with purchase of TL-4100*
TL-4060 VALUED AT $54.95

ARDUINO® COMPATIBLE MODULES, SHIELDS & ACCESSORIES

$4.20

STACKABLE HEADER SET

HM-3207

- Gold flash 0.1 pitch quality stackable headers.

$4.95

LOGIC LEVEL CONVERTER MODULE

XC-4486

Drops straight into solder-less breadboard or can be soldered into your own PCBs.

- Two bi-directional channels
- 12-pin DIL package

NEW

$4.95

AVR ISP 10PIN TO 6PIN ADAPTOR

XC-4613

- Use with an ISP programmer to update bootloaders or reflash bricked boards
- 10 pin plug to 6 pin socket

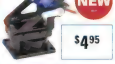
NEW

$4.95

SOIL MOISTURE SENSOR MODULE

XC-4604

Automate your garden with Arduino® and detect when your plants need watering.



NEW

$4.95

PAN AND TILT ACTION CAMERA BRACKET MOUNT

FOR 9G SERVOS XC-4618

An easy way to add pan/tilt functionality to your robot or Arduino® project.

- Easy to assemble
- Clamp for servo wires
- Servos not included, use YM-2758.

$8.95

MINI PROTOTYPE BOARD SHIELD

XC-4480

Solder-pads and small breadboard included.Fully compatible with Arduino®, Duinotech LEONARDO, Duinotech Classic.

$9.95

INFRARED OBSTACLE AVOIDANCE SENSOR MODULE

XC-4524

Perfect for robotics projects, also works with our pcDuino module using the 3.3V output. Includes two potentiometers, one to control frequency and one to control intensity.

- 5VDC operation
- 4 pin header
- 42(L) x 27(W) x 18(H)mm

NEW

$9.95

RAIN SENSOR MODULE

XC-4603

- 5V supply required
- Adjustable sensitivity, LED indicator
- TTL level output can drive 100mA, enough for a small relay or buzzer

NEW

$9.95

TRIPLE REFLECTANCE SENSOR MODULE

XC-4611

- CTRT5000 Sensor IC
- 5V supply required
- 2 pins for power and 3 for outputs

NEW

$19.95

DC-DC BOOST MODULE WITH DISPLAY

XC-4609

- Output 5V-56V, input 3.5V-35V
- 2A input current without heatsinking
- Solder terminals

$9.95

3-AXIS COMPASS MAGNETOMETER MODULE

XC-4496

Take accurate compass bearings, no matter how it is oriented. Easily interfaced via I²C.

- 12bits resolution
- Includes 5V - 3V level shifter

$9.95

TEMPERATURE AND HUMIDITY SENSOR MODULE

XC-4520

- Fully digital operated
- Resistive type humidity measurement
- Response wavelength 200-370nm
- 43(L) x 13(W) x 8(H)mm

ARDUINO® COMPATIBLE RELAY BOARDS

Provides the easiest way to use your Duinotech to switch real world devices. Available in one, four & eight channel versions.

- Status LEDs show channel status
- Screw terminals for easy connection to relay contact
- SPDT Relays

1 CHANNEL 5VDC
40(W) x 27(D) x 18(H)mm XC-4419 **$4.95**

4 CHANNEL 12VDC
77(W) x 55(D) x 17(H)mm XC-4440 **$12.95**

8 CHANNEL 12VDC
135(W) x 50(D) x 19(H)mm XC-4418 **$19.95**

$4.95
XC-4419

$12.95
XC-4440

$19.95
XC-4418

ARDUINO® COMPATIBLE PROTO SHIELD KIT

XC-4555

Build your own Arduino® shield using the compact and flexible Proto Shield kit. Solder together a limitless range of circuits and reuse it in all your Arduino® projects. A standard 0.1" prototyping grid accepts commonly used through-hole parts and chips.

See website for full contents.

$19.95

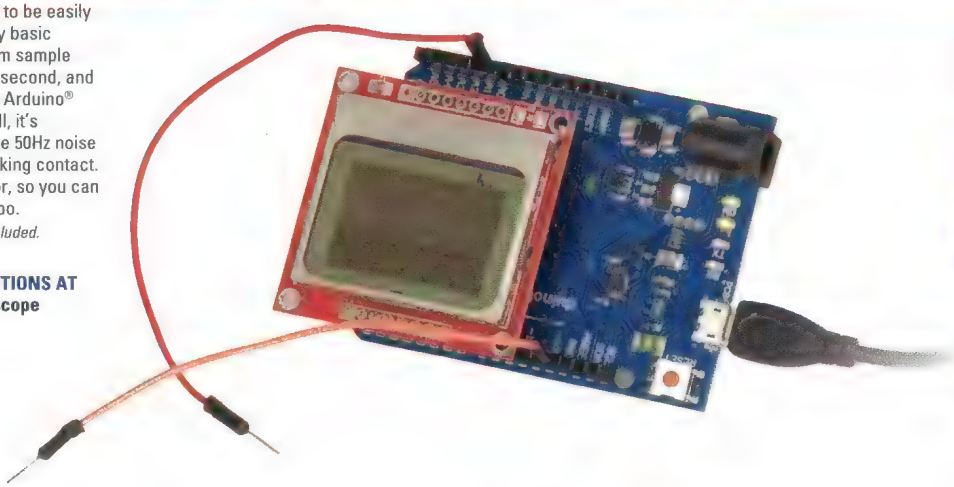
NEW

ARDUINO® COMPATIBLE OSCILLOSCOPE

This little test tool is designed to be easily put together if you need a very basic scope in a hurry. The maximum sample rate is about 700 samples per second, and it's limited to the 0-5V that the Arduino® analogue pins can handle. Still, it's sensitive enough to pick up the 50Hz noise from mains wiring without making contact. Also includes a tone generator, so you can compare signal frequencies too.

USB A to USB Micro B Lead not included.

SEE STEP-BY-STEP INSTRUCTIONS AT www.jaycar.com.au/oscilloscope



NERD PERKS CLUB OFFER
BUY ALL FOR $45
SAVE OVER $10

DIY

MORE INFO ONLINE

DUINOTECH LEONARDO BOARD
XC-4430

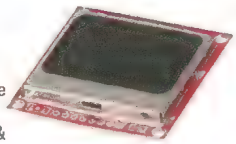
- Combines the chipset for the main controller and USB in a single IC.
- Boasts 12 analogue inputs and an extra PWM channel
- 75(W) x 53(L) x 13(H)mm

$29.95

84X48 DOT MATRIX LCD DISPLAY MODULE
XC-4616

Identical to those found in some old Nokia phones, & featuring the PCD8544 chipset. An easy & small black and white graphics display for your project.

- 8 pin plug
- SPI interface



NEW

$19.95

150MM PLUG TO PLUG JUMPER LEADS - 40 PIECE
WC-6024

- Various colours for prototyping.
- Ideal for Arduino® and DIY projects. Pins suitable for breadboards or PCB headers.

$5.95

PRACTICAL ARDUINO BOOK BM-7132

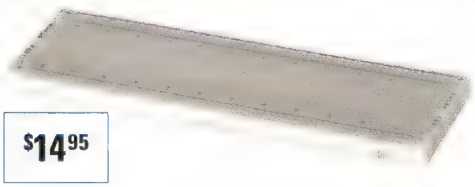
Provides detailed instructions for building a wide range Arduino® compatible projects covering areas such as hobbies, automotive, communications, home automation, and instrumentation. Soft cover, 422 pages.

$54.95

SOLDERLESS BREADBOARD
PB-8815

With labeled rows and columns and adhesive back for mounting, it is ideal for electronic prototyping and Arduino® projects.

- 830 tie points
- 165(L) x 54(W) x 9(H)mm

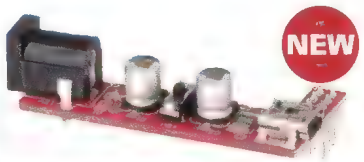


$14.95

ARDUINO® COMPATIBLE BREADBOARD POWER MODULE XC-4606

Receiving power from a USB socket or DC socket, this module adds a compact power supply to your breadboard.

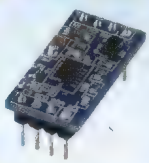
- Plugs straight into most breadboards
- Can be set to 3.3V or 5V
- Concave design saves space



NEW

$9.95

SAVE 10% ON THESE ARDUINO® COMPATIBLE ACCESSORIES



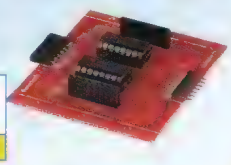
NOW $8.95
SAVE 10%

DIGITAL TILT SENSOR MODULE
XC-4484 **WAS $9.95**

Low power consumption, compact capacitive micromachined acceleration sensor. Supports 5V input, onboard RT9161, a lower pressure drop than the 1117; and faster loading time. Ideal for noisy power environments. 5VDC rails.

- 73(L) x 29(W) x 23(H)mm

Limited stock. Not available online.



NOW $15.25
SAVE 10%

8 X 8 DOT MATRIX DRIVER MODULE
XC-4532 **WAS $16.95**

Driven by shift registers it requires only three inputs.

- 5VDC operating voltage
- Daisy-chainable
- 74HC595 chipset
- 72(L) x 69(W) x 12(H)mm

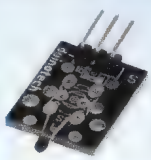
NOW $17.95
SAVE 10%

FAN WITH PROPELLER MODULE
XC-4534 **WAS $19.95**

Driven by a L9110H full H bridge driver, allows you to develop your own speed control project. Easily blow a light flame at a distance of 20cm. 75mm propeller dia.

- 5VDC working voltage
- 29(L) x 22(W) x 10(H)mm

Limited stock. Not available online.



NOW $17.95
SAVE 10%

TEMPERATURE SENSOR MODULE
XC-4538 **WAS $19.95**

Features 0.5°C accuracy and fast response. Perfect for building your temperature-sensitive projects or even add on to your home automation system or data loggers.

- -55°C - +125 °C temperature range
- 20(W) x 15(L) x 5(H)mm

Limited stock. Not available online.

ALL THE TOOLS OF THE TRADE FOR YOUR PROJECTS

There has been an obvious resurgence in people getting back to the workbench and reviving skills involving manual dexterity. As you will see across the following pages, Jaycar has all the DIY tools you'll need to equip your workbench so you can create projects from the power of your brain and your hands.

MINI TRUE RMS AUTORANGING DMM
QM-1570

Compact, IP65 (weather resistant) and been drop tested to height of 2m.

- Cat III 600V, 4000 count
- Non-contact AC voltage detection
- Duty cycle %
- Min/Max, Data hold
- Temperature (Probe incl.)
- Auto power off

Due early August

MAGNIFYING LAMP WITH THIRD HAND
TH-1989

Equipped with LED illuminated 3x magnifying glass, soldering iron stand, alligator clips, solder spool holder, cleaning sponge & ball.

- 4 x AA batteries required (not included)
- 190(W) x 170(D)mm (base size)

TOOL MAGNETISER / DEMAGNETISER
TD-2042

Suitable for even the largest of screwdrivers.

COLOUR-ADJUSTABLE LED TABLE LAMP
SL-3139 **WAS $69.95**

- 3500-5500K colour temperature
- 270 Lumens (max) illumination
- Base 360° swivel

COMPONENT LEAD FORMING TOOL
TH-1810

Provides uniform spacing from 10 to 38mm.

SELF-HEALING BENCHTOP WORK MAT HM-8100

- Ruled with 1 centimetre spaced grid for easy referencing
- 3mm thick- 450 x 300mm

270° ROTATION CLAMP VICE

TH-1769

Clamp to any bench or table up to 55mm thick and the 40mm jaws will take a job up to 58mm in size. The head is easily fixed in position with a quick release lever.

- 115(W) x 94(D)mm base size

$29.95

ILLUMINATED GOOSENECK MAGNIFIER

QM-3532

Includes 2 x main lenses and 5 x insert lenses with the bonus of 2 LED lights. The magnifier is clip-on or free standing. Suitable for surfaces up to 38mm thick. Includes metal stabilisers and flexible neck.

- Lens 95mm (dia.), stands 225mm high
- Protective lens pouch
- Requires 3 x AAA batteries (Sold separately)

$29.95

DESK MOUNT LED LABORATORY MAGNIFIER LAMP

QM-3546 **WAS $109**

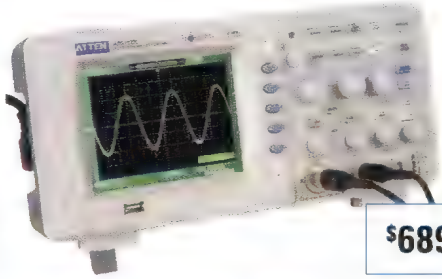
This is a high quality, all metal frame construction magnifier. Features 90 super bright LEDs. and a quick repositioning metal handle.

- 3 dioptre magnification
- Eextended length: 900mm
- Generous 2 metre long cord

NOW $99
SAVE $10

FREE HIGH QUALITY BANANA PIGGYBACK TEST LEADS FOR NERD PERKS CARD HOLDERS*
WT-5326 **Valid with purchase of MP-3800*
WT-5326 VALUED AT $29.95

$149



$689

0-24VDC 15A COMPACT SWITCHMODE LABORATORY POWER SUPPLY MP-3800

Compact size, high current, variable output and fan cooling make these the ideal power supply for your bench. Protects against thermal overload and short circuit and will display a warning LED in the event of a fault condition.

- 148(W) x 162(D) x 62(H)mm

ALSO AVAILABLE: 30A 0-16V MP-3802 **$199**

25MHZ DUAL CHANNEL DIGITAL OSCILLOSCOPE WITH 5.7" SCREEN QC-1932

Trace capture, PC interface, storage of data on portable media, on-screen menus, mathematical functions etc.

- USB interface & storage memory
- Multiple trigger modes, digital filters & multi-parameter auto measure function
- Sampling rate: 500MSa/S
- 310(W) x 150(H) x 130(D)mm

WIN 1000 NERD PERKS POINTS!

SUBMIT A PHOTO OF YOUR WORKBENCH OR PROJECT USING JAYCAR PRODUCTS AND YOU COULD WIN 1000 NERD PERKS POINTS. THAT'S A $50 JAYCOINS CARD!

win.jaycar.com/workbench

Competition closes 23rd Aug. See website for the T&Cs

$6.95

SOLDER SUCKER & BLOWER BULB
TH-1850

Cheap, compact and effective. Approximately 50(D) x 110(L)mm.

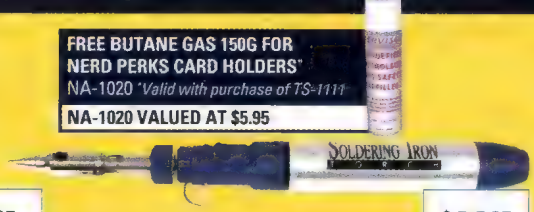
$9.95

SOLDERING IRON STAND TS-1502

A general purpose stand for virtually any electronics soldering iron. It has a large, thirsty tip cleaning sponge & pressed metal base.

SPARE SPONGE TO SUIT TS-1503 **$2.75**

FREE BUTANE GAS 150G FOR NERD PERKS CARD HOLDERS*
NA-1020 *Valid with purchase of TS-1111*
NA-1020 VALUED AT $5.95

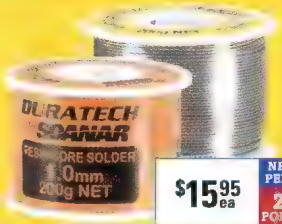


$26.95

GAS SOLDERING IRON TS-1111

This butane gas soldering iron features adjustable tip temperature and a fold-out stand. Remove the soldering tip and you have a flame torch for heatshrink. 210(L) x 20(dia)mm.

SPARE CATALYST TS-1104 **$14.95**
1MM CONICAL TIP TS-1105 **$4.95**



$15.95 ea

NERD PERKS 2x POINTS

DURATECH SOLDER

60% Tin / 40% Lead.

200GM 0.71MM NS-3005
200GM 1MM NS-3010

See in store or website for our full range of solder.

PVC INSULATION TAPE

Top quality PVC tape. Two sizes. 20M available in black, white, blue, red, and yellow/green. 19mm wide.

BLACK 5M NM-2800 **$1.25**
20M NM-2801/2/3/4/7 **$2.75 EA.**

FROM $1.25

NERD PERKS 2x POINTS

9ML WIRE GLUE
NM-2831

A soldering iron in a jar. Electrically conductive adhesive that enables you to make solder-free connections when you don't have a soldering iron handy. Lead-free, cures overnight.

$9.95

NERD PERKS 2x POINTS

25ML J-B WELD EPOXY
NA-1518

An easy and inexpensive alternative to welding, soldering and brazing. Two-part epoxy resin that forms a compound as tough as steel. Bonds to almost any surface.

$14.95

NERD PERKS 2x POINTS

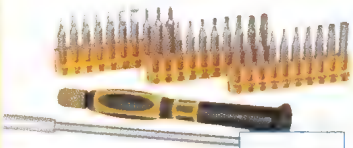
250G DUST REMOVER SPRAY CAN NA-1018

Non-CFC, non-flammable gas. No residue. Non-toxic and non-conductive.

See instore or online for our full range of service chemicals.

$19.95

NERD PERKS 2x POINTS



$18.95

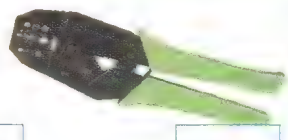
32 PIECE PRECISION DRIVER SET
TD-2106

High-quality driver set with all those really small bits. Tactile handle with hardened hex shaft that extends from 140 to 210mm. Storage case included.

$29.95

STAINLESS STEEL CUTTER / PLIERS
TH-1812

Set of five 115mm cutters and pliers for electronics, hobbies, beading or other crafts. Soft ergonomic grips.



$39.95

5 WAY CRIMPING TOOL
TH-1829

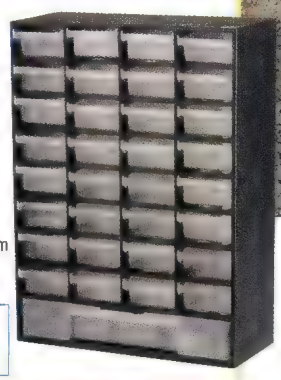
Cut wire & bolts, crimp insulated and non-insulated terminals, and strip wire.

See website for details.

33 DRAWER PARTS CABINET
HB-6330 **$29.95**

Ideal for workshop use and can be wall mounted. 8 rows of 4 pull out drawers, plus one full width pull out drawer.

- Each draw is 65mm wide and 125mm deep
- 414(H) x 304(W) x 135(D)mm



$29.95

iPHONE® REPAIR TOOL SET TD-2115

Helps you dissasemble and re-assemble your iPhone® that needs to be repaired.

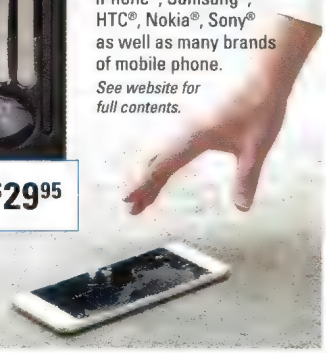
See website for full contents.

$16.95

27 PIECE SMARTPHONE REPAIR KIT TD-2118

Designed to repair iMac®, Mac® Air, iPhone®, Samsung®, HTC®, Nokia®, Sony® as well as many brands of mobile phone.

See website for full contents.



$29.95

10% OFF THESE WATCH TOOLS FOR NERD PERKS CLUB MEMBERS

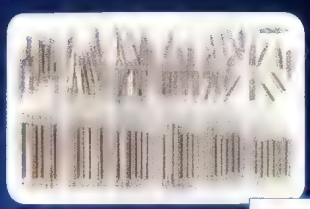
WATCH CASE HOLDER
TH-1934

$12.95

WATCHMAKERS MALLET TH-1927

6 diifferent heads, ball pein

$14.95



WRIST WATCH STRAP SPRING BAR ASSORTMENT
TH-1928

360pc.

$24.95

JEWELLER'S SCREWDRIVER SET TD-2023

Set of six, housed in a handy storage case

- Slotted: 1.0, 1.2 & 1.6mm
- Phillips: #00, #0 & #1

$9.95

$34.95

FOUR PIECE WATCHMAKERS KIT TH-1932

Case retainer with 18 retaining lugs, a large dusting bulb pump, No. 7 tweezers and fine dusting brush.

$39.95

WATCH BRACELET LINK REMOVER TH-1923

Includes a 1.0mm and 0.8mm pin removal insert.

IP54 ABS PLASTIC MOLDED ENCLOSURES

High impact, flame retardant ABS to UL- 94 VO. Tongue and groove joints. IP54 of IEC 529. NEMA4.

90 X 50 X 16MM HB-6030 **$4.95**
90 X 50 X 24MM HB-6031 **$5.95**
120 X 60 X 30MM HB-6032 **$7.95**
150 X 80 X 30MM HB-6034 **$12.95**
190 X 100 X 40MM HB-6036 **$18.95**

FROM $4.95

ABS JIFFY BOXES

Compliant with industry standards. Suitable for screen printing. Lids feature a 5mm grid of 'centre punch' type points on the underside for drilling. PCB guides include snap-in locators.

- Supplied with lid fixing screws and safety concealment plugs

BLACK 158 X 95 X 53MM HB-6011 **$4.45**
BLACK 197 X 113 X 63MM HB-6012 **$6.95**
BLACK 130 X 68 X 44MM HB-6013 **$3.95**
BLACK 83 X 54 X 31MM HB-6015 **$2.95**
GREY 130 X 68 X 44MM HB-6023 **$3.95**
GREY 83 X 54 X 31MM HB-6025 **$2.95**
CLEAR 83 X 54 X 31MM HB-6005 **$2.95**

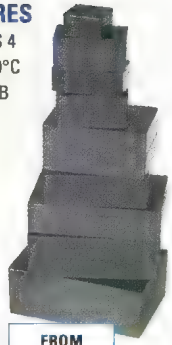
FROM $4.45

IP65 SEALED ABS ENCLOSURES

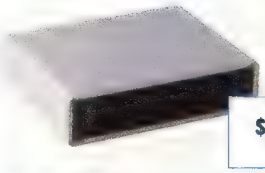
Designed to IP65 of IEC529 and NEMS 4

- Operating temperature: - 20°C to 100°C
- Internal guide slots for mounting PCB assemblies vertically

64 X 58 X 35MM HB-6120 **$5.95**
115 X 65 X 40MM HB-6122 **$8.95**
115 X 65 X 55MM HB-6124 **$9.95**
115 X 90 X 55MM HB-6126 **$12.95**
171 X 121 X 80MM HB-6129 **$21.95**
171 X 121 X 55MM HB-6128 **$17.95**
222 X 146 X 75MM HB-6132 **$28.95**
240 X 160 X 90MM HB-6134 **$37.95**



FROM $5.95



$6.25

INSTRUMENT ENCLOSURE

HB-5970

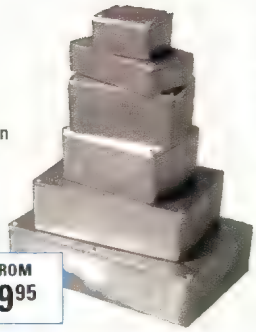
Removable ABS front & rear panels.

- 140(W) x 110(D) x 35(H)mm

SEALED DIECAST ALUMINUM ENCLOSURES

Designed to IP65 of IEC529 anf NEMA 4. Effective shielding of EMI and RFI. Lid incorporates a recessed EPDM gasket. Made from Aluminium alloy ADC- 10 to Japan Industrial Standard (JIS) in natural finish .

64 X 58 X 35MM HB-5030 **$9.95**
115 X 65 X 30MM HB-5036 **$14.95**
115 X 65 X 55MM HB-5040 **$18.95**
115 X 90 X 55MM HB-5042 **$21.95**
171 X 121 X 55MM HB-5046 **$34.95**
222 X 146 X 55MM HB-5050 **$36.95**



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Gasket seals, stainless steel hardware and IP66 rated for use in industrial, marine and other harsh environments. Includes a 1.8mm galvanised chassis for mounting DIN rail, switchgear, relays or circuit breakers.

OPAQUE LID LARGE HB-6404
200(L) x 200(W) x 130(D)mm
TRANSPARENT LID MEDIUM HB-6412
175(L) x 125(D) x 75(H)mm

$34.95 ea

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FROM 95c

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14500 800MAH 3.7V SB-2300 **$9.95**
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26650 3400MAH 3.7V SB-2315 **$24.95**
SOLDER CONNECTION:
14500 800MAH 3.7V SB-2301 **$10.95**
18650 2600MAH 3.7V SB-2313 **$21.95**
26650 3400MAH 3.7V SB-2319 **$25.95**

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NI-MH RECHARGEABLE BATTERIES

- No memory effect
- Higher current capacity than Ni-Cd batteries
- High drain performance

1.2V AAA 900MAH - 4 PACK SB-1739 **$11.95**
1.2V AA 2000MAH - 4 PACK SB-1737 **$15.95**
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$24.95

UNIVERSAL NI-CD/NI-MH BATTERY CHARGER

WITH CUT-OFF MB-3514

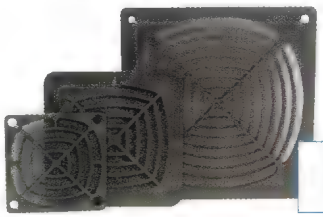
Recharges: AAA, AA, C, D and 9V batteries

- Cut-off function
- Accepts various combinations of batteries
- 199(L) x 100(W) x 46(H)mm

FROM $3.95

FAN GUARDS

80MM YX-2511 **$3.95**
120MM YX-2515 **$4.95**
150MM YX-2525 **$8.95**



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Foam filter prevents dust particles entering the fan.

- Made from plastic rated to UL 94V- 0.
- Available in 3 sizes

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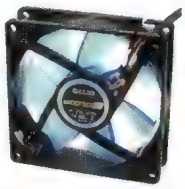

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SUPER LONG-LIFE LOW-NOISE

Nanoflux bearings. 100,000hrs operational life at 40°C (even longer at 25°C). Dust and waterproof to IP54. Flylead with 3 pin molex.

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Long service life, up to 100,000 hours at 25°C.

80MM FLYLEAD YX-2508 **$36.95**
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BUILD YOUR OWN MOTION ACTIVATED LED LIGHTING SET UP
VALUED OVER $104

Impress your friends as your LED lights automatically light up as they walk past your workspace. An easy to build, efficient and affordable lighting solution.

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12V SWITCH CONTROLLER WITH PIR SENSOR ST-3940
Switches on lights or other 12VDC powered devices when movement detected.

$29.95

12VDC 2.5A SWITCHMODE MAINS ADAPTOR MP-3490
- Input: 100-240VAC 50/60Hz
- Huge power output
- Supplied with 7 plugs
- Meets MEPS requirements

$49.95

ULTRA BRIGHT IP67 WATERPROOF LED FLEXIBLE STRIP LIGHT ZD-0579
- 12VDC
- 1 metre

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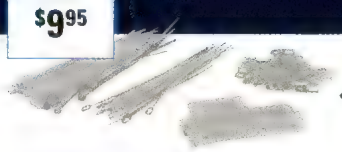
BUY ALL FOR $89
SAVE 15%

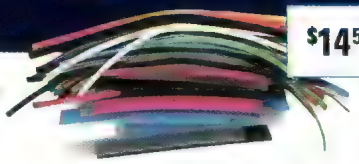
DIY

$9.95



CABLE TIE TIDY KIT HP-1198
Keep your cabling neat and tidy. Consists of: 30 x 120mm cable ties, 20 x 120mm reusable cable ties, 10 x self adhesive cable tie mounts, 20 x saddle type cable tie mounts.

$14.50



THE ULTIMATE HEATSHRINK PACK WH-5520
1 length each of 7 different colours in 7 different sizes ranging from 1.5mm dia to 20mm.

$19.95

CABLE TIES HP-1216
400 pieces of black cable ties supplied in a storage box. Kit consists of: 100 pcs x 200mm, 100 pcs x 150mm, 200 pcs x 100mm.

$34.95

42 PIECE ASSORTED SOLDER SPLICE HEATSHRINK PACK WH-5668
Quickly create sealed soldered joint in one go. Each splice has just the right amount of solder to create a secure and well-insulated connection. Includes assorted colours and sizes to suit various cable size. *See website for full contents.*

$8.95 NERD PERKS 2x POINTS

1/4 WATT CARBON FILM RESISTORS - 300 PIECES RR-1680
This pack includes five of virtually each value from 1 Ohm to 10 Meg. Sixty different values.

ALSO AVAILABLE:

1/2W 1% MINI SIZE METAL FILM RESISTOR PACK 300 PIECES RR-0680 **$16.95**

FROM $9.95 NERD PERKS 2x POINTS

CAPACITOR PACKS

CERAMIC CAPACITOR PACK 10pF - 100NF - 60 PIECES
RC-5399 **$9.95**

GREENCAP CAPACITOR PACK 0.001µF - 0.22µF- 60 PIECES
RG-5199 **$11.95**

MKT CAPACITOR PACK 0.001µF - 0.47µF - 50 PIECES
RM-7190 **$16.95**

ELECTROLYTIC PACK 1µF - 470µF- 55 PIECES
RE-6250 **$13.50**

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TRANSISTOR PACK
ZT-2170
100 Mixed BC series transistors. Includes:
- 15 x BC547
- 15 x BC558
- 20 x BC548
- 15 x BC559
- 20 x BC549
- 15 x BC557

FROM 95c

BANANA PLUGS
RED 4MM PLUG PP-0400 **$0.95**
BLACK 4MM PLUG PP-0402 **$0.95**
RIGHT ANGLE RED PP-0394 **$2.25**
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FROM $1.25/m

AC MAINS CABLES
TWO CORE MAINS FLEX 7.5A
WB-1560 **$1.25/M**
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FROM $2.25

ROCKER SWITCHES
30A 12VDC RED LED ILLUMINATED
SK-0955 **$4.95**
10A 250VAC SPST SK-0960 **$2.25**
See instore or online for our full range of switches.

$34.95

LIGHT DUTY HOOK-UP WIRE PACK
8 COLOURS WH-3009
Quality tinned hook-up wire. 8 rolls included, each roll a different colour.
- 25m on each roll

$27.95

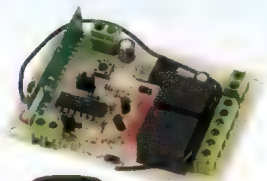
72VA SINGLE WINDING TRANSFORMER MM-2012
Type 2158 single winding transformer with 20mm fly leads on primary and secondary connections.
- 24V, 72VA, 3A rated

2 CHANNEL REMOTE CONTROL RELAY BOARD LR-8855
Each output relay is controlled by a separate button on the key fob controller.
- Operates at 433MHz
- Works up to 40m with rolling code transmitting for added security.
- 85(L) x 61(W) x 20(H)mm

ALSO AVAILABLE:

4 CHANNEL REMOTE CONTROL RELAY BOARD LR-8857 **$59.95**

SPARE 2 CHANNEL KEY FOB CONTROLLER LR-8856 **$15.95**



$49.95

4-CHANNEL WIRELESS REMOTE CONTROL RELAY
WITH 2 KEY FOBS LR-8824
Control up to 4 different devices with a single controller and key fob remote.
- 10 - 15VDC, 350mA max
- 30m transmission typical (300m+ max line of sight)

SPARE REMOTE LR-8829 **$24.95**

SPARE HARDWIRED REMOTE LR-8819 **$39.95**

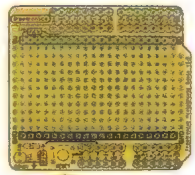
$99.95

ARDUINO® COMPATIBLE ACCESSORIES AT BARGAIN PRICES

PROTOSHIELD BASIC
XC-4214

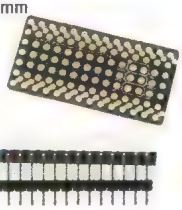
A low-cost Arduino® prototyping shield that enables you to make more durable or permanent projects. Gold plated.
- GND and 5V rails beside prototyping area
- 59(L) x 53(W)mm

JUST $4.95



LEOSTICK PROTOTYPING SHIELD
XC-4268 **WAS $9.95**
- 64 general-purpose plated holes
- Includes male header pins
- 36(W) x 19(H) x 2(D)mm

NOW $6.95
SAVE $3



DUAL CHANNEL IR REFLECTANCE SENSOR
XC-4261 **WAS $14.95**

Use as a pair or cut/snap it in half for two separate reflectance sensors.
- 37(W) x 9(H) x 3(D)mm

NOW $9.95
SAVE $5

SOUND & BUZZER MODULE
XC-4232 **WAS $13.95**

Can be used for both input and output.
- 1 to 25V rated voltage (3 to 5V typical)
- Built-in 1M resistor for knock sensor functionality
- 23(W) x 16(H) x 5(D)mm

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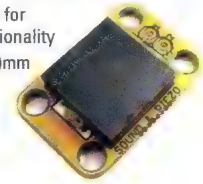
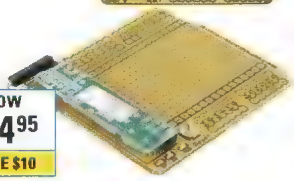
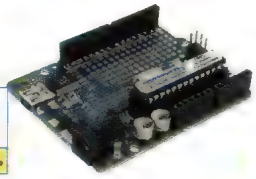




NOW $24.95
SAVE $10

433MHZ RECEIVER SHIELD
XC-4220 **WAS $34.95**

Lets you intercept 433MHz OOK/ASK signals, decoding them in software on your Arduino®.
- Reset button
- 433.92MHz tuned frequency



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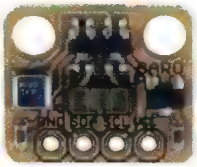
SAVE OVER 35%

ELEVEN (100% ARDUINO® UNO COMPATIBLE) XC-4210 WAS $39.95

Microcontroller board based on the ATmega328 (see website for datasheet). Includes 14 digital I/O pins, 6 analogue inputs and more.
- 18(W) x 18(H) x 5(D)mm



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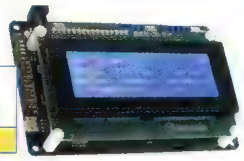
BAROMETRIC PRESSURE SENSOR
XC-4255 **WAS $33.95**

Highly sensitive barometric pressure sensor for weather, industrial, rocketry, balloon, and many pressure applications. Designed specifically for use as a micro altimeter.
- 15(W) x 13(H) x 5(D)mm



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STEPDUINO BOARD
XC-4249 **WAS $169**

A complete, self-contained board perfect for building robots or other mechatronics projects.
- 2 x 4-wire stepper motor controllers
- 1 x servo interface, and more.

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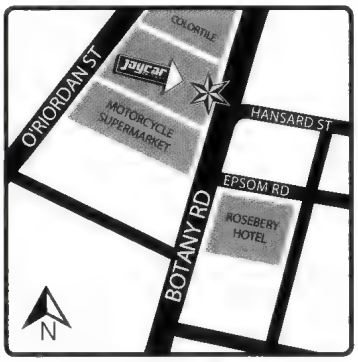

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Arrival dates of new products in this flyer were confirmed at the time of print but delays sometimes occur. Please ring your local store to check stock details. Occasionally there are discontinued items advertised on a special / lower price in this promotional flyer that has limited to nil stock in certain stores, including Jaycar Authorised Stockist. These stores may not have stock of these items and can not order or transfer stock.

SERVICEMAN'S LOG

The ISP help desk from hell

Dave Thompson*

Arranging an internet service for our new house while keeping an existing service for our current house should have been a simple procedure. Not so for our local ISP provider who have just put me through help-desk hell.

Items Covered This Month

- Dave's help-desk hell
- Rolling machine repairs
- Faulty Australian Monitor AMC+120 audio amplifier

It's been a rough month; once again, I've been thrust into the public hospital system, though this time my Dad is the patient.

I've mentioned Dad before in the context of the Serviceman's Log as the most influential of my mentors, teaching me engineering from a very early age and planting the seeds that grew into a fascination of all things mechanical and electronic. To see Dad in his present state is terrible but as I write this, his prognosis is cautiously optimistic, which is miraculous considering he suffered what is typically a non-survivable event.

As if things weren't difficult enough, my wife and I are currently renovating a recently-purchased house and workshop across town. When completed, it will become our new home and my new workplace.

If you've ever renovated anything larger than a hall closet, you'll know that it's an enormous job. And along with all the tasks there are a hundred other little things to be done, such as arranging phones, insurance, an internet service, power and gas and so on. However, things didn't go too smoothly when I called our internet service provider (ISP) to arrange for the internet to be connected at the new house.

At the moment, we have a relatively brisk 50Mb/s cable connection that allows us to browse the web and download stuff with no pesky waiting. It was natural then for us to want a similar broadband set-up at our new place. The company that originally set up that cable network had sold out to another company a few years ago but our custom had simply been transferred across to the new company and everything had carried on as normal.

The cable Internet ring around Christchurch was installed around 10 years ago and yet strangely, many areas of the city aren't covered. I clearly remember the salespeople door-knocking everyone in Christchurch at the time and as I understood it, if two households on any given street signed up for the proposed new cable service, the telco would run the cable down that street. This meant that some small streets offered it while some larger thoroughfares didn't.

No cable

Unfortunately, our new address doesn't have the cable laid, so cable Internet simply isn't available. As luck would have it though, this new ISP offers Ultra-Fast Broadband (UFB) and with plans including 100Mb/s and 200Mb/s fibre-optic connections, this seemed like a more than decent alternative. However, when I called to ask about it, the help-desk lady apologised for the fact it would take at least eight weeks for UFB to be connected to our new address. As we'd be in the house long before that, they could offer us a "standard" ADSL connection in the meantime. It would only give us a paltry 10Mb/s on a good day with a tail wind but it was better than nothing.

After some thought, I agreed to this arrangement and rang off with the understanding that the technician who was to connect the ADSL would call me the following day to arrange a site visit. The next few days then passed quickly, with most of my time taken up with tearing out a very dated kitchen, laundry and bathroom so that renovations could begin.

As arranged, the phone contractor eventually called and said that he would be around to wire up the place the following day. He duly turned up, connected everything in place and a quick test with the new modem they had previously couriered out to us proved that we were online. Now we just had a few more weeks to wait for the UFB connection to be installed!

My mood darkens

I was happy with the new ADSL connection but my mood quickly darkened when I got home that afternoon to our "old" house (which we are keeping) to find that the internet was down. With a sense of foreboding, my first thought was that they'd cut us off instead of keeping the current connection alive as arranged. My suspicion was that they'd done a service

Servicing Stories Wanted

Do you have any good servicing stories that you would like to share in The Serviceman column in Silicon Chip? If so, why not send those stories in to us? In doesn't matter what the story is about as long as it's in some way related to the electronics or electrical industries, to computers or even to car electronics.

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Please be sure to include your full name and address details.

"relocation", which of course meant cutting us off "here" when connecting us "there".

I hate calling help lines at the best of times; it's often difficult to get anything done, even after you actually get through to someone. Therefore, it was with dread that I telephoned the ISP's help desk and after the obligatory waiting period and ghastly piped music, the operator confirmed my worst fears.

That was when I could actually hear what she was saying; she was so quiet on the line that I had to keep asking her to speak up!

Finding out that they had indeed made a mistake was something I didn't need to hear at that time of the day; we were under enough stress as it was. That said, I could accept that they had made a mistake but I now wanted them to rectify it and to do so as quickly as possible. I'd already spent some 15 minutes on hold before they'd answered and my mood was rapidly deteriorating.

My suggestion at that point was to get whoever disconnected us to reconnect it, as my wife needed the internet to work from home the next day. After again asking her to speak up so that I could hear what she was saying, she then put me on hold while she went and asked someone what was going on. After another 10 minutes, she was back and said that she was transferring me to the contractor who had, in her words, "climbed up the pole and disconnected us".

At least, I think that's what she said. I admit that my hearing is not the best after years of playing in bands and spending my teen years racing model aircraft with very noisy motors but I was sure that it was her low voice (and not my hearing) that was causing our communication difficulties. Quite simply, that bit about climbing up the pole didn't sound right to me but what would I know? Perhaps that's how they did it with cable connections?

All I knew was that I could ping my modem and gateway, so it seemed we were still physically connected to the system at any rate. I just couldn't send or receive any data through it.

After another holding period, where the recorded message chimed in over the music every 30 seconds to tell me that my call was important, an operator answered. When I explained the whole story to him, he said he had no idea why the ISP would bounce me to them because they could do nothing without an order from the ISP. What's more, he informed me that they controlled the cable connections and nobody climbs up poles to connect or disconnect subscribers.

As can be imagined, I was rather miffed by now but managed to stay nice and calm while I was transferred back to the ISP. Eventually, after another wait, the same quiet woman answered the call and after a brief recap of what the contractors had said, put me on hold yet again to go and talk to her manager. I was certainly rediscovering why I so dislike calling so-called help desks but since I still had a good hour before the close of business for the day, I was cautiously optimistic of being reconnected that evening.

When the operator came back, I again had to ask her to please speak louder so that I could hear her. She then began by saying that the only way we could get reconnected was to apply for a new connection. When I asked how long that would take, she replied "a couple of weeks"!

I couldn't believe it. This was so obviously not a resolution to this problem that I almost laughed out loud. I asked her if she would be happy with that if she was in my shoes but I didn't hear what her answer was.

By now, I'd had enough and asked to be put through to her manager. She responded that it was her manager who had told her to offer a new connection and despite my insistence that I wanted to speak to someone else, she seemed very reluctant to put me through. And she again told me that a contractor had come to our address, climbed the pole and disconnected us, and it wasn't simply a matter of

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him coming back and hooking it up because they'd moved our service to our new place.

She then offered to put through another relocation order and have the service moved back but as this would also take a few weeks, that wasn't going to fly. I interrupted her, my manners fast disappearing and demanded I talk to her manager. She put me on hold for another five minutes before returning and telling me he had gone home for the day.

No call-back

Eventually, after further argument and more gnashing of teeth, she told me that she would have to talk another manager. She also told me that she would call me back within the hour. Three hours later, I finally accepted that she wasn't going to be calling back.

So much for their help desk. It was now obvious that we'd be without an internet service for the night, which is of course a first-world problem and no real biggie for us. However, it meant that I'd have to call first thing in the morning and argue the case again if Nina was to have connectivity the next day so that she could work from home.

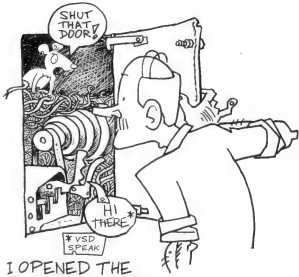
Round two the next morning initially couldn't have been more different. Unlike the previous evening, I got straight through to a young technical operator who scoffed when I reported what his colleague had told me the previous day. And he was horrified to learn that she didn't call back.

He checked the records and discovered that she hadn't notated any of the conversation we'd had, so he was in the dark about what the problem was. When I told him, he said that all they needed to do was to reactivate the connection in their system and we'd be away.

As he was talking, I could hear him typing and after about 30 seconds he asked me to reboot my cable modem and see if we had connectivity; I did and the world was once again at our fingertips. But why couldn't that silly woman I'd spoken to the previous day do that or at least put me through to someone who could? It was all quite baffling and left me more than a little annoyed. I was very satisfied with this guy's help though and when he asked me if there was anything else he could help me with, I asked him about the UFB connection at the new place.

He again looked through the records and discovered that no order had been placed for it to be installed! As I said earlier, I had previously ordered the UFB installation weeks ago when the ISP representative made arrangements for the stop-gap ADSL service. It now had to be reordered which meant that we would be bumped back to the end of the queue.

These companies exasperate me! They make millions and their CEOs enjoy a privileged lifestyle, yet they continually fall short with customer service. Anyway, he said he'd have to transfer me to someone who could help with that and after a short hold period, who should come onto the line but the same woman from the day before! And I still couldn't hear her!



After asking her to yet again please speak louder, I outlined what we wanted for the new place, which was to get in the queue for UFB. She went through the same questions I had answered weeks previously but for the sake of not making waves, I patiently answered them all again.

It all went OK until she asked whether we'd be having a monitored alarm and then things started getting weird. I answered "yes" and then she said they couldn't give us UFB because they couldn't guarantee the alarm monitoring would work. I told her that the alarm used the phone line, which was a completely separate system from the fibre that was yet to be installed, so it wouldn't matter. She told me that the engineers would remove the copper line system altogether before installing fibre, so that would affect the alarm.

Thoroughly taken aback by this, I told her that another telco provided those copper wires and that we were happy with their service. I also told her that I seriously doubted that their contractors would remove another telco's wires but she was adamant that they would remove the copper lines altogether. By this time my blood pressure was dangerously high, so my wife, who had been listening over my shoulder, took over the conversation.

Nina couldn't make much sense of what she was saying either but it appeared that the operator was trying to tell us that in order to have UFB connected, we had to ditch our current telephone provider and use their system instead. And that sounded completely wrong to me. Their website contradicted everything this woman was saying, so we went through the whole "let me speak to someone else malarkey" before Nina simply hung up when it became obvious that she wasn't going to put us through.

We ended up going to one of their stores in the local mall and after 10 minutes' conversation, we were in the queue for UFB, with our existing copper lines intact. This has to be my worst help-line experience ever and I won't be calling them again any time soon.

Rolling machine repairs

A couple of rolling machines recently provided a real challenge for G. S. of Montrose, Tasmania but he was able to eventually get them rolling again. Here's what happened . . .

I was recently called out to check a "D" profile gutter-rolling machine. The operator complained that he was getting a shock at times when feeding the steel into the machine, so the job was urgent.

The feed arrangement was fairly simple. First, the flat metal strip was pushed into the machine by hand until it engaged the first set of rollers. The operator then used an "inch" button located on the side of the machine, behind a low steel handrail, to mechanically drag the strip in a little further, after which the machine was ready to run.

Sometimes, however, he needed to lean over the handrail and give the

Serviceman's Log – *continued*

Faulty AMC+120 audio amplifier

Nobody likes a trip to the dentist but music can help calm those waiting-room nerves. G. C., of The Gap, Qld was recently called on to fix the audio amplifier in one such practice and unlike the patients, it put up quite a struggle . . .

My eldest son owns a busy dental practice in a Queensland coastal town and to soothe the nerves of his trembling patients, he plays relaxing music via an Australian Monitor AMC+120 amplifier. He tells me that the amplifier is now many years old and was repaired by the manufacturer's agent just over two years ago. When it failed again recently, the agent had a look at it and advised my son to replace it, given "its age".

So, on his next trip to Brisbane, the amplifier was duly delivered to me to see if it was indeed uneconomic to repair. The first thing I noticed about it was its not insignificant weight, due mainly to a very large power transformer and a large toroidal-core output transformer for the 100V speaker feed.

When I subsequently removed the top cover, I noticed that it had three PCB assemblies: (1) a preamp board catering for four inputs, (2) a mixer and tone/volume control board and (3) a main amplifier and power supply board. These boards were daisy-chained together by ribbon cable, each terminating in a plug/socket assembly.

Switching the unit on, I found that it was as dead as a doornail with not even the power indicator LED lit. It was soon apparent that the 8A DC fuse was open circuit but the 2A AC fuse was intact. What was surprising though was that the DC fuseholder had partially melted. I also discovered that solder from the ends of the ceramic M205 fuse had been deposited into this fuseholder, so clearly there was a major fault.

I checked every semiconductor on the main amplifier board but couldn't find any short circuits. The fuseholder had a minuscule amount of metal touching the fuse-caps so I surmised that the contact resistance led to heating and subsequently complete failure. I replaced the fuseholder with one which had a large contact area, so hopefully this type of failure will be eliminated in the future.

On the main board there were four 2-way screw terminal blocks. One of these was used to terminate leads from the power transformer and had melted due to a very loose connection. By contrast, its companion terminal block was fine.

After this part had been replaced, I turned my attention to the electrolytic capacitors on the main board. There were only six and two had an unacceptably high ESR so I replaced all of them.

In order to test the amplifier, I connected the output to one of my Wharfedale speaker boxes. Unfortunately, it had appreciable mains hum and when the volume control was advanced to near maximum, the unit squealed but not with delight. I disconnected the cable between the mixer board and the main amplifier and it was as quiet as a mouse. However, when I re-connected these two boards but disconnected the preamp board, the hum and instability remained.

This indicated that the problem was due to a fault on the mixer board. This board had 23 electrolytic capacitors and I checked each for capacitance and ESR. All were within tolerance. I then discovered some poor-looking solder joints, so I re-soldered the entire board. During this process, one of the copper pads around the lead of an electrolytic capacitor literally fell off and had to be repaired.

Feeling hopeful that the hum problem had now been cured, I re-installed the board and switched the amplifier on. However, there was no improvement.

I don't know why but I only seem to use my oscilloscope as a last resort. I stoked it up and found that the power supplies were clean and that there was little noise on the op amp inputs and outputs. In the end, all my prodding and probing revealed nothing and so my inherent reluctance to use an oscilloscope felt validated.

By now though, there was a bell ringing but I only heard a faint tinkle until I finally realised that it might be an earthing problem. There were two earth leads in the ribbon cable between the main amplifier and the mixer boards and I checked the continuity of these with my ESR meter. They were intact, as were the earth leads from the mixer to the preamp board.

strip a bit of a nudge to get it moving and this is when he was receiving the shocks.

The steel rail was bolted directly to the floor and had no connection to the machine. I checked the voltage between the rail and the machine and there was no reading to speak of but that all changed when the inch button was pressed. As the speed control ramped up, so did the potential difference between the machine and the handrail, the reading quickly heading for 100V or more.

So what was going on? The control cabinet was a free-standing metal console type enclosure with a number of disused buttons and switches. It looked as though it had been salvaged from some other machine and the installer didn't bother to clean it up.

I opened the control cabinet to be greeted by an ancient VSD (variable speed drive) and a rat's nest of wire, all liberally covered in hydraulic oil and caked-on dirt. The earthing arrangement consisted of a stud on the case with the clamp nut almost completely unwound. It was probably only being kept in place by the dirt lodged in the last couple of threads!

I cleaned it all up and clamped down the earth properly but it made no difference to our problem; the voltage between the machine and the handrail still climbed with the VSD speed.

Next, I checked the earthing between the control cabinet and the machine and found there wasn't any. I fitted a temporary earth and the voltage disappeared. That meant that there had to be a problem with either the VSD, the motor or the connecting cable (or perhaps all three).

I placed a clamp meter on the feed earth to the machine and ran the motor at full speed. The current increased to over 2A, so there was current leakage somewhere. The VSD was not complaining about earth faults but it was an old unit and might not have had the internal diagnostics to indicate that sort of problem.

No cable screening

The motor was a very nice 18kW ASEA unit in very good order. However, the motor cable wasn't screened and was simply lying on the floor soaked in oil and subject to all sorts of abuse.

In the end, we decided to stop chasing the fault and to rebuild the control gear. He had purchased a number of old machines over the years and we had salvaged quite a bit of equipment that was still in good order. This meant

The preamp board itself was earthed to the chassis via a cable that was terminated in an eyelet at the chassis end and clamped by a metal-thread screw. When I checked this earth, I discovered that it was open-circuit, mainly because the black powder-coated finish on both sides of the chassis had not been removed. Even though serrated washers had been used on both sides, they had obviously oxidised over time.

I fired up my trusty Dremel and ground the coating off both sides of the chassis, then reattached the earth wire. The earth resistance then measured just a couple of hundredths of an ohm. I also checked the mains earth which had been installed the same way as the signal earth. It read just 0.2Ω but I removed it and ground off the coating to ensure its reliability, before reattaching it.

This time, when the amplifier was switched on, the hum and instability were completely absent. However, when I connected a CD player to the amplifier, I was dismayed to find that the sound was extremely distorted at lower frequencies. I tried to borrow a neighbour's audio function generator to help troubleshoot this problem only to find that it had died quite some time ago.

As an afterthought, I connected the amplifier to my other speaker box and was greeted with perfect sound at long last. It turned out that the woofer in the first box that I used was poling badly and will need extensive surgery. These Wharfedale speakers (E50 Series) are only 35 years old, so it just goes to show that they don't make things the way they used to!

that I was able fit a reasonably new Italian Santerno VSD, Swiss-made control buttons, Japanese circuit breakers, a Korean-made length-measuring counter and a German-made encoder into a the console, along with a new fully-screened cable to the motor.

That got it all running nicely again and there were no further shocks.

Following my success with that job, I was then called out a couple of weeks later to look at a fascia rolling machine. This is a similar set-up to the gutter roller but uses different roller profiles and was made by a different manufacturer. The machine was still working but was it making a racket that sounded rather like a collapsed bearing in the motor, clutch or gearbox.

Unlike the gutter roller, there was no speed control. Instead, the motor ran continuously and was connected to a very large worm-drive gearbox via an air-driven clutch/brake system. It wasn't super accurate but it didn't need to be.

In order to troubleshoot the problem, we needed to pull the motor and gearbox assembly out. Unfortunately, it's all buried down inside the frame of the machine, which is essentially a large steel box with all the roller stations bolted on top and coupled up by large (100mm) bike chains. That meant that in order to get to the motor, these roller stations had to be removed.

Welded roller stations

Unfortunately, whoever built the machine had way too much faith in the longevity of the power train and had decided to weld the roller stations in place. As a result, it took a fair bit of grinding to remove the stations, after which a crane was used to remove the motor/gearbox assembly.

We soon found that the fault lay in the clutch unit. Its bearings were seriously damaged but it was too old to get an off-the-shelf replacement, which meant that a new one would have to be made. The owner then decided that it wasn't worth repairing and instead asked me to make up a new control panel with a proper speed control, just as I did for the gutter rolling machine.

After digging through his store of parts, I came up with a SEW VSD, another Chinese-made cabinet and a few assorted switches. The only parts I needed to purchase were a new encoder and a counter.

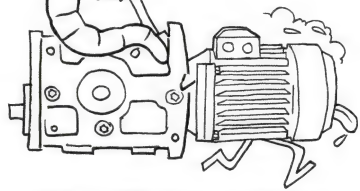
It all went together quite well and I even managed to find a book for the VSD, so I was able to get that programmed without too much trouble. It all seemed to work OK, so the roller stations were welded back into place. We didn't have time to come up with a different mounting arrangement, because by now there was a backlog of work and we needed to get the machine back into operation.

Some time later, the machine's operator reported that the counter was freezing every now and then (and without warning), which meant that it wasn't shutting the roll off at the set length. This was a real problem when specified 12m lengths kept on going and hit the factory wall. As a result, the operator was now hanging over the emergency stop button just in case.

Interference

It was all a bit of a mystery but I suspected interference from the VSD, as this unit didn't seem to have any EMC components built in. My guess was that noise was probably finding its way onto the encoder cable which was quite long, so I clipped a ferrite choke around it. That seemed to improve things but it wasn't a complete cure.

In the end, I took the "more is better" approach and clipped ferrite chokes around the power supply and control wiring leading to the counter, plus an extra one on the encoder cable. That did the trick and the machine now performs without any problems. SC



~THE MOTOR RAN CONTINUOUSLY & WAS CONNECTED TO A VERY LARGE WORM-DRIVE GEARBOX

By Geoff Graham

Micromite Plus & the Explore 64

This module really packs a punch. Based on our new Micromite Plus, it's more than twice as powerful as the original Micromite, with much faster performance, substantially more RAM, greater program space (flash memory), more I/O pins, support for a wide range of touchscreen displays (up to 8-inch!) and additional functions including support for USB, SD cards and a PS/2 keyboard. It can act as a sophisticated controller or as a completely self-contained computer.

THE MICROMITE PLUS is based on a PIC32 chip and is a revised version of the 28-pin and 44-pin Micromites described in SILICON CHIP over the past couple of years (see Table 1). While the standard Micromite was intended for ordinary controller jobs, the Micromite Plus is much more advanced and can handle more demanding applications (such as machine controllers).

To quantify some of the improvements, the Micromite Mk2 (described in January this year) runs at 48MHz and has 52KB RAM and of 58KB program space, with between 19 and 33 I/O pins available depending on the version (28-pin or 44-pin). By comparison, the Micromite Plus runs at 120MHz, boasts 100KB RAM, 100KB of program space and in the version described here, has a massive 47 I/O pins available, many of them analog-capable.

The Micromite Plus can run very large programs very fast; 2.5 times as fast as the previous Micromite, in fact. It can also drive LCD touchscreens with a diagonal size of between 1.44 and 8 inches (~37-163mm), with a sophisticated graphics library. That library allows you to create animated radio buttons, numeric keypads, push-buttons and many more GUI elements using just one line of BASIC code.

In addition, the Micromite Plus has an SD card driver and a USB 2.0 interface, giving it the capability to work as a self-contained computer.

This article touches on some of the new Micromite Plus software features and also describes the Explore 64 module, designed for breadboarding. In addition to hosting the PIC32 chip running the Micromite Plus software and breaking out the I/Os, serial console and power pins, it carries an onboard USB socket, a microSD card socket, a 3.3V regulator, a reset button and an optional supply supervisor.

In coming months, we will also

Key Improvements From Micromite Mk2

- 2.5 times the speed
- 92% more RAM
- 72% more program space
- More I/O pins
- Integrated USB
- Supports 10 different touchscreen displays
- Comprehensive GUI library code
- Native SD card support
- MicroSD card socket
- Cheaper to build than 44-pin Micromite

The Micromite Plus is just a standard 64 or 100-pin Microchip PIC32MX470 microcontroller programmed with the MMBasic firmware. It is this firmware that transforms the micro into an easy to use programmable controller that can interface with multiple devices, ranging from LCD panels to SD cards and PS/2 keyboards. Photo courtesy Microchip.

describe the Explore 100, a full Micromite Plus-based computer with display, keyboard support and SD card storage, with even more I/O pins thrown into the bargain.

Touch-sensitive LCDs

The Micromite Plus includes support for 10 different types of LCD panel and as previously stated, these range from a 1.44-inch module to an 8-inch panel. Note that imperial units are commonly used for LCD panels and the specified size is the diagonal measurement of the active screen area. For example, a 5-inch panel is typically around 11 x 7cm while an 8-inch panel would be about 17 x 10.5cm.

The Micromite Plus supports displays that use both serial and parallel interfaces. There are six supported display sizes that use serial (SPI) interfaces, between 1.4 and 2.8 inches diagonal, using ILI9341, ST7735 or ILI9163 controller chips. The ILI9341 is the same chip that was used in the Micromite LCD BackPack (introduced in February) but support for the ST7735 and ILI9163 controllers is new in the Micromite Plus.

Four different displays with parallel interfaces are also supported. These range from 4.3 to 8 inches and it is with these displays that the Micromite Plus really stands out. They can display text and graphics in true 24-bit colour with a resolution of up to 800 x 480 pixels. As a result, you can display vivid photo-quality images with 16 million colours.

The parallel interface between the Micromite Plus and the display controller on the LCD panel means that your BASIC program can update the display very quickly, even though it is addressing almost half a million pixels in full 24-bit colour. This sort of performance is important when you are displaying intricate graphic objects such as radio buttons, check boxes and virtual keypads.

GUI commands

The Micromite Plus has all the BASIC graphics commands supported by the standard Micromite (**PIXEL**, **LINE**, **BOX**, **CIRCLE**, etc). But it also has a range of Graphical User Interface (GUI) commands that are both powerful and easy to use.

For example, by using a GUI command, you can define a check-box on the screen. When this is touched, it will be checked with a cross and when touched a second time it will be unchecked. This checking and unchecking is handled in the background (by the MMBasic interpreter) without involving the main BASIC program.

Another example is the text box. This is an on-screen box which, when touched, will display a full alphanumeric keyboard, allowing text to be entered and edited via the touch-sensitive screen.

These are just two examples of the controls built into MMBasic and the range is extensive. Included are radio buttons, switches, pushbuttons, multi-colour LEDs, numeric keypads and spin boxes.

MMBasic handles all the drawing, animation and interface requirements for GUI elements. All that the BASIC program needs to do is define the on-screen control (with a single command) and from then on, MMBasic

Explore 64: Main Features

- A 32-bit CPU running at 120MHz with 512K of flash memory and 128K RAM.
- Built in BASIC interpreter is Microsoft compatible with 64-bit integer, floating point and string variables, arrays and user defined subroutines and functions.
- 47 input/output (I/O) pins which can be independently configured as digital inputs or outputs. 27 of these can be used as analog inputs.
- The Explore 64 can be plugged into a standard solderless breadboard, or into a protoboard or a custom PCB via standard female headers.
- Supports touch-sensitive LCD panels ranging from 1.44 inches to 8 inches diagonal. Supports LCDs with up to 16 million colours. Built-in graphics commands include pixel, line, circle and box.
- Six built-in fonts plus many more fonts that can be embedded in a program.
- Advanced graphics commands include on-screen keyboards, buttons, switches, checkboxes and radio buttons.
- USB 2.0 interface which creates a serial-over-USB communications channel for program editing and upload/download from a larger computer.
- SD card interface supports SD cards with up to 64GB capacity. Up to five files can be opened simultaneously for read, write and random access.
- Provision for a PS/2 keyboard so that the Explore 64 can act as a fully self-contained computer and development system.
- All the standard features of the Micromite range, including a comprehensive range of communications protocols, inbuilt commands to directly interface with devices such as an IR remote control and temperature sensors, PWM or SERVO outputs and special embedded controller features such as variable CPU speed, sleep, watchdog timer and automatic start and run.
- Power supply: 5V @ 80mA (not including LCD current drain, etc).

Table 1: Micromite Articles In Silicon Chip

Title	Publication Date
The Micromite	May & June 2014
ASCII Video Terminal	July 2014
The 44-pin Micromite	August 2014
The Micromite Mk2	January 2015
Micromite LCD BackPack	February 2016

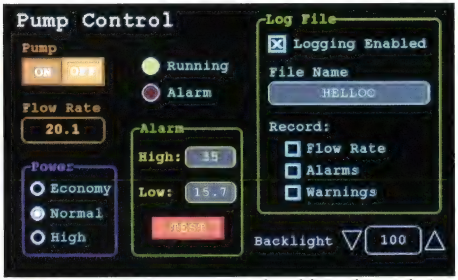


Fig1: this is an example of an on-screen control panel that can be created using the Explore 64 and an LCD panel. Most objects on the screen are touch-sensitive and will react when touched. Each is created with a single BASIC command and from then on MMBasic will manage the display, including animating the objects when a user touches them. We will describe these GUI controls in detail in a later article.

does the rest. The BASIC program flow is unaffected by this activity and can later inspect the state of the control using a single function.

Fig.1 shows an example of a complex pump control panel that is constructed from GUI commands. Each object on the screen required just one line of BASIC code to create it. The GUI controls will be described in detail in article in this series.

SD card & keyboard

The Micromite Plus includes support for SD cards with capacities up to 64GB, formatted as either FAT16 or FAT32. Programs can be loaded and saved to the SD card and up to five data files can be open at the same time from within a BASIC program. These files can be opened for reading, writing or random access. The latter provides quick access to any part of a file and is useful for storing and recalling large amounts of data.

Images held on the SD card can be loaded under program control and displayed on the attached LCD to add screen logos or background images. The files created on the SD card are compatible with Windows, Linux or Macintosh systems, so data can be easily transferred from the Micromite Plus to a desktop computer for analysis.

Another important feature of the Micromite Plus is the ability to attach a PS/2 keyboard. This allows the Micromite Plus to be the heart of a fully self-contained computer, with programs composed and edited on the LCD and saved to an SD card. This is reminiscent of the TRS-80 and Commodore 64 computers of the 1970s and the Maximite series of computers featured in SILICON CHIP in recent years.

MMBasic includes its own colour-coded program editor, so an external computer is not required for the user to compose, edit and run their own programs on the Micromite Plus. If you wish, you can also compose and edit programs on a larger desktop or laptop computer and transfer them to the Micromite Plus using the USB interface or the serial console.

PIC32 microcontroller

The Micromite Plus firmware will run on a number of Microchip PIC32 microcontrollers with either 64 or 100 pins (see Suitable Microcontrollers panel). All come in surface-mount TQFP packages but their pin pitch is a relatively forgiving 0.5mm, so they can be hand-soldered to a carrier board. SILICON CHIP sells suitable carrier boards, ie, www.siliconchip.com.au/Shop/18/3227 and www.siliconchip.com.au/Shop/18/3218

Note, however, that this type of adaptor normally has pins along all four edges and so it is not suitable for plugging into a breadboard, while the Explore 64 is.

The PIC32 microcontrollers listed in the panel each have an optimised MIPS 32-bit processor core which can run at up to 120MHz and supports 512KB of flash memory and 128KB of RAM. This might sound complex and daunting but they are not expensive and the complexity is hidden by the MMBasic interpreter.

This month, we are presenting the Explore 64 which uses the 64-pin version of the chip, while a future instalment will introduce the Explore 100 which uses the 100-pin chip and is designed to mount on the back of a 5-inch LCD panel (although it can be used stand-alone or with a different display).

Explore 64

The Explore 64 is a small PCB designed by SILICON CHIP reader Graeme Rixon of Dunedin, NZ. It can be plugged into a solderless breadboard for prototyping and for exploring the capabilities of the Micromite Plus but could also be used as a replaceable module that's plugged into a larger system.

The PCB includes a 64-pin PIC32 (the Micromite Plus), a mini USB connector, a microSD card socket and the power supply parts. There are 47 I/O pins. Of these, 17 are 5V tolerant, while 27 can be used as analog inputs. So there's plenty of capability to develop a complex project that requires lots of I/O ports.

In order to make it small enough to fit onto a breadboard, the PCB was designed using surface-mount components. Despite this, it's not difficult to build. IC1 (the microcontroller) uses a 0.5mm spacing between its pins and can be hand-soldered using a normal temperature-controlled soldering iron. In addition, the solder pads for the passive components will accept either 1206, 0805 or 0603-size components, so you can use whatever size suits your soldering skills.

Circuit details

Fig.2 shows the circuit details of the Explore 64. It's designed to run from a 5V supply and this can be fed in via USB socket CON1, if jumper JP1 is fitted. Alternatively, if JP1 is removed, the 5V supply can be fed in via the 5V IN and GND pins on the board's edge.

The 5V supply is reduced to 3.3V by low-dropout linear regulator REG1, an MCP1703A. The resulting +3.3V rail is then used to power microcontroller IC1 and is also made available on an

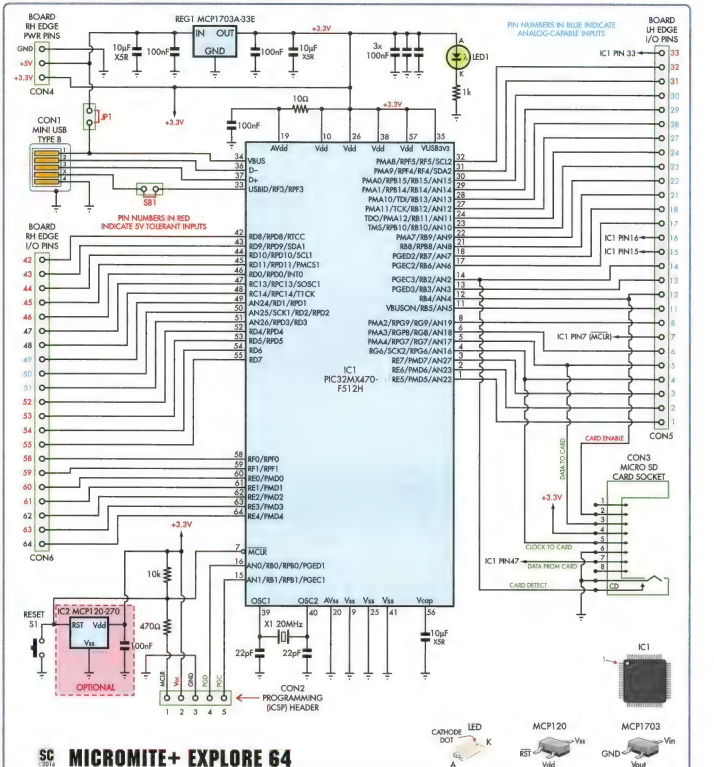


Fig.2: the Explore 64 is mostly a carrier for the 64-pin Micromite Plus (IC1), so its circuit is relatively simple. Most I/O pins from the microcontroller are made available on the board's edge where they can be plugged into a solderless breadboard or into header sockets on a larger board. Voltage regulator REG1 provides 3.3V for the microcontroller and the reset supervisor (IC2) ensures that the microcontroller is held in reset if the 3.3V supply drops below a critical level.

I/O pin on the board's edge for powering external circuitry.

The capacitors across the supply lines before and after the regulator ensure regulator stability and reduce variations in supply voltage with changing current demands. Note the capacitor connected between pin 56 of IC1 and ground. This stabilises IC1's internal 1.8V core regulator and must be a multilayer ceramic type, preferably with an X5R or X7R dielectric.

Ideally, all capacitors should be X5R or X7R ceramic types except for the 22pF crystal load capacitors which

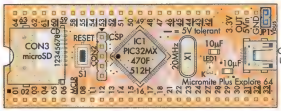
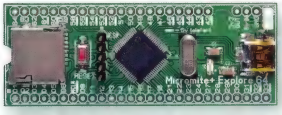
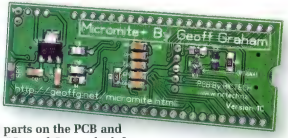


Fig.3: follow these top and bottom PCB parts layout diagrams to build the Explore 64. The top of the PCB (left) carries most of the parts including the microcontroller, SD card socket and USB connector, while most of the power supply components and I/O pin headers are on the bottom side.





Compare these photos with the layout diagrams when installing the parts on the PCB and check that all polarised parts are correctly orientated. CON1-CON3, IC2 and S1 can be left off if they are not required but most constructors will want to fit them.

should be C0G/NP0 ceramic. As a bonus, these capacitors tend to have a very long life (practically indefinite).

I/O pins

Most of IC1's I/O pins are connected to pads along the sides of the PCB, as depicted on either side of the circuit diagram and in Table 2, along with pads for the +5V and +3.3V supply rails and ground. CON3 is the microSD card connector. The I/O pins used for this connector are also brought out to the sides of the PCB so that they can be used as general purpose I/O pins if the microSD connector isn't used.

IC2 (bottom left of Fig.2) is an optional "supervisor" chip. This holds the Micromite Plus in reset until the 3.3V power supply reaches a set level (2.7V in this case). It will also monitor the 3.3V line and reset the microcontroller if there is a glitch or if the supply drops to a low value (a brown-out condition). IC1 has an internal brown-out detector but its threshold is much lower and external circuitry could stop working well before this trips.

The supervisor chip will be important if the Micromite Plus is used in an industrial situation where power fluctuations and electrical noise are common. In other situations, the supervisor chip is not critical and so IC2 and its associated 100nF capacitor can be left out with no ill-effects. We'll be supplying the MCP120-270 in our kits, so you might as well fit it anyway; it certainly won't hurt.

CON2 is an in-circuit serial programming (ICSP) header and this allows the Micromite Plus firmware to be loaded into a blank microcontroller. It suits a Microchip PICkit 3 programmer or similar.

The only other items of note are the USB socket, which connects directly to IC1, and a 20MHz crystal which is used as the clock source for IC1. SB1 is a solder bridge which should be left open; it's included to give the option of supporting a USB device (such as a USB keyboard) in a future firmware upgrade.

Construction

Building the Explore 64 is reasonably easy despite the fact that it uses SMD components. Soldering SMD devices is not that much harder than soldering through-hole components; it just requires a different technique and is easy when you have mastered it.

The essential tools are a good magnifier, plenty of flux and a steady hand. The magnifier needs to be at least x3 power and preferably x10. A jeweller's loupe can be used but the best option is a stereo microscope and Silicon Chip reviewed some good candidates in the July 2014 and November 2015 issues.

The flux should be a good quality flux paste/gel such as Cat. H1650A from Altronics or Cat. NS3036 from Jaycar.

Fig.3 shows the parts layout on the Explore 64 PCB. The first step is to install microcontroller IC1. Apply flux to all of its pads, then position the chip so that its pin 1 (marked with a dimple)

Suitable Microcontrollers

The Micromite Plus uses Microchip's MX470 series chips. These are part of Microchip's PIC32 (32-bit processor) range and are available in 64-pin and 100-pin packages with top speeds of 100MHz or 120MHz.

The Micromite's firmware starts up at 100MHz so you can use chips with either speed. However, a 120MHz version gives you option of stepping up to 120MHz in your program.

The recommended chips for the Micromite Plus are:

- PIC32MX470F512H-I/PT: 64-pin, 100MHz
- PIC32MX470F512H-120/PT: 64-pin, 120MHz
- PIC32MX470F512L-I/PF: 100-pin, 100MHz
- PIC32MX470F512L-120/PF: 100-pin, 120MHz

Silicon Chip will supply the 120MHz version in all cases, ie, for individually purchased programmed PICs as well as in kits.

Table 2: Explore-64 I/O Pin Allocations

SSD1963 D5 - ANA	1		64	63	ANA - SSD1963 D4
SSD1963 D6 - ANA	2		63	62	5V - SSD1963 D3 - PWM1C
SSD1963 D7 - ANA	3		62	61	ANA - SSD1963 D2
SPI2 CLOCK - ANA	4		61	60	5V – SSD1963 D1
SPI2 OUT - ANA	5		60	59	5V – SSD1963 D0
CONSOLE Rx	6		59	58	5V – COM1 Rx
CPU Reset when Low			58	55	CONSOLE Tx
SPI1 OUT - ANA	8		55	54	5V - KEYBOARD DATA
COM2 Tx - ANA	11		54	53	5V - KEYBOARD CLOCK
ANA	12		53	52	5V - PWM 2A
COM2 Rx - ANA	13		52	51	5V - COUNT
ANA	14		51	50	ANA - COUNT - WU - IR
COM1 Tx - ANA	15		50	49	ANA - SPI1 CLOCK
COM3 Tx - ANA	16		49	48	ANA - COUNT
COM3 Rx - ANA	17		48	47	PWM 1A
ANA	18		47	46	SPI2 IN - PWM 2B
ANA	21		46	45	5V
ANA	22		45	44	5V - SPI1 IN
COUNT - ANA	23		44	43	5V - I²C CLOCK
SSD1963 WR - ANA	24		43	42	5V - I²C DATA
SSD1963 RS - ANA	27		42	41	5V - PWM 1B
SSD1963 Reset - ANA	28				
COM1 Enable - ANA	29				
ANA	30			32	3.3V OUTPUT (100mA MAX)
5V	31			31	5V OUTPUT OR INPUT
5V	32			30	GROUND
DIGITAL INPUT ONLY	33				

(1) Pin Nbr refers to the number used in MMBasic to identify an I/O pin; (2) All pins (except 33) are capable of digital input/output and can be used as an interrupt pin; (3) ANA means that the pin can be used as an analog input; (4) 5V means that the pin is 5V tolerant; (5) COUNT means that the pin can be used for counting or frequency/period measurement; (6) SSD1963 refers to pins that are used to interface to LCD panels using the SSD1963 controller; (7) If the serial console is disabled the CONSOLE pins can be used for COM4

Note: the Explore 64 is shown here scaled up by a factor of almost 2.

is lined up with the pin 1 marking on the PCB (at left). That done, hold it in position using a toothpick or tweezers and solder one corner pin.

Now check that the IC is correctly aligned; if not, re-melt the solder while gently nudging it into position. Once it's in position, apply more flux to all the pins and solder each one in turn, then recheck the first pin and add fresh solder if necessary.

The technique here is simple; put a very small amount of solder on your iron's tip, touch the tip to the solder pad and slide it forwards to gently touch the first pin. The solder should flow around the pin and the pad. You should then be able to solder at least 15 more pins (one side of the IC) before you need to add more solder to the iron.

The secret is to be generous with the flux, as this will allow the solder to flow freely onto the pads and their corresponding pins. Alternatively, if you have a mini-wave tip or a very steady hand, with sufficient flux in place, you can drag solder across one side (16 pins) in a single movement.

Often you will find that you are actually soldering two or more pins simultaneously but the solder will not usually bridge the pins. If it does, this is an indication that you have too much solder on your iron. If any pins are bridged, come back later with solder wick (and more flux) and remove the excess.

The SD card connector is next on the list. It's located on the PCB by two small plastic pins that match two holes on the board. Solder its four mounting lugs first, followed by the signal pins. These pins are soldered using the same technique as for IC1.

Note that the SD card connector's pins are fragile and the plastic they are embedded in will melt if too much heat is applied so only touch the soldering iron to the pins for a very short time. As before, apply plenty of flux before soldering.

The mini-USB connector can now go in. It also has locating pins to posi-

A Microchip PICkit 3 can be used to load the firmware into the PIC32 micro. Alternatively, you can buy a pre-programmed PIC32 chip from the SILICON CHIP Online Shop.

tion it correctly and you should push it down firmly so that it sits flush against the board. Once again, solder the mounting lugs first and then the signal pins. These are a bit of a challenge as they are partially under the connector's body and you will need a fine-tipped soldering bit to reach them; we have extended the pads outside the body to make this easier.

Passive SMD components

Soldering the passive SMD components requires a different technique compared to that used the microcontroller. Start by applying flux to one solder pad and then tin it by applying a thin layer of solder to it. That done, you have two choices.

First, you can place the component in position and hold it still with a toothpick or tweezers while you apply the iron's tip to the end sitting on the tinned pad, so that the component's lead sinks into the solder underneath. Alternatively, you can slide the component into place while heating the solder on the pad. The second technique will probably require more practice but it will be quicker once you get used to it.

Either way, once the component is secure, apply more flux and solder the other end before returning to the first to make sure that the joint is good. Once again, the secret is to use plenty of flux and don't forget that it may have boiled off one of the pads while you were soldering the other end of the component, so keep reapplying it.

LED1 (the power indicator LED) is polarised and should be marked with a bar or dot on the cathode end. Some LEDs might be different so it's good practice to use a multimeter's diode test facility to check the polarity. Be sure to solder it in with its cathode towards the bottom of the board, as shown in Fig.3.

You can use a similar technique as used for the passives to solder regulator REG1 and IC2 (if this is to be fitted). The only trick is that with REG1, you first apply flux to all four pads and then start by soldering one of the smaller leads. That done, check its alignment before soldering the other smaller leads and finally the large tab. It may take a few seconds to heat the part and PCB up enough to get a good solder joint on that tab.

Crystal X1 is a through-hole part and can be soldered using the usual method. PCBs supplied by SILICON CHIP will have solder mask over the top side of the mounting pads so it should be possible to push the crystal can right down onto the PCB surface before soldering it.

That just leaves tactile pushbutton S1 (which can be fitted either way around) and the various pin headers, which are made by snapping longer pin headers to length and then soldering them in the usual manner. Normally, JP1 and CON2 should be fitted on the top of the board, with the other pin headers on the bottom (see Fig.3). CON2 does not need to be fitted if you have a pre-programmed PIC chip.

Loading firmware into the PIC32

Pre-programmed PIC32s are available from the SILICON CHIP Online Shop. If using a blank PIC32 chip, you will need to program it yourself. In this case, you will need a suitable programmer such as a PICkit 3 from Microchip.

The Explore 64 has a set of header pins on the top surface labelled ICSP and the PICkit 3 plugs directly onto them (see photo at left).

The first step is to download the firmware from the SILICON CHIP website and extract the Micromite Plus HEX file (0710816A.hex). It's then just a matter of using your computer and the MPLAB software supplied with the PICkit 3 (or downloaded from Microchip) to program the HEX file into the microcontroller (see page 26 of the February 2016 issue for further details).

During this procedure, the PICkit3 will verify the programming operation by reading back the data on the chip. If it reports a fault, you will need to fix that before progressing. Usually though, the programming operation

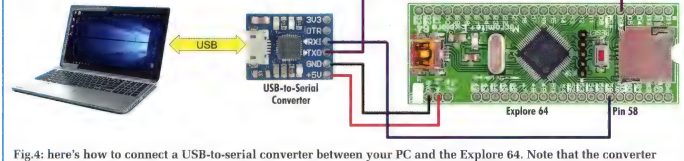
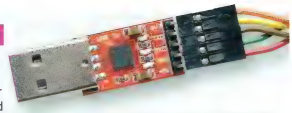


Fig.4: here's how to connect a USB-to-serial converter between your PC and the Explore 64. Note that the converter can supply the 5V power required by the Explore 64 but you also need to fit jumper JP1 (see text).

USB-to-Serial Converter



A USB-to-serial converter such as this CP2102-based unit from the SILICON CHIP Online Shop is necessary in order to use the serial console when developing or editing programs. This unit is supplied complete with a short DuPont cable and plugs directly into your PC's USB port (which also supplies the power). The DuPont cable then connects between the converter and the Explore 64 as shown in Fig.4.

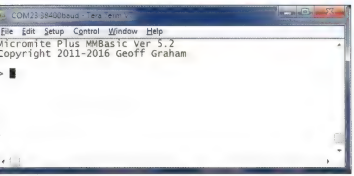


Fig.5: this is what you should see in your terminal emulator when you press the reset button on the Explore 64. If you don't see this, the probable reason is that the USB-serial converter is not connected correctly.

will be verified as OK, indicating that the PIC32 has been correctly programmed.

Serial console

To set up and use the Explore 64, you must connect a terminal emulator to its console. The console is a serial interface over which you can issue commands to MMBasic to configure the chip and edit or run programs. MMBasic also uses the console to display error messages.

The Explore 64 actually has two consoles, one serial and one USB. The USB console is useful for making quick changes to a running program or for developing a program where the Explore 64 is being used as a general-purpose computer. However, if you are using the Explore 64 as a controller, it's best to use the hard-wired serial console via a USB-to-serial converter.

The reason for this is that when the Micromite Plus PIC32 is reset, it will also reset its USB interface. This generally means that you must close the terminal emulator then restart it to restore the connection. When you are developing a program for controlling other equipment, you often need to reset the Micromite Plus and repeatedly closing and re-opening the terminal emulator can get tedious.

A USB-to-serial converter is required in order to use the hard-wired serial console. One end of this converter plugs into a USB port on your computer, while the other end connects to the Explore 64's serial console (Fig.4). To your computer it will look like a serial port (via USB), while the connection to the Explore 64 is a standard serial interface with TTL (0-3.3V) signals levels.

We recommend converters based on the CP2102 chip. These are available from the SILICON CHIP online shop at www.siliconchip.com.au/Shop/7/3437 It is supplied with a short DuPont female/female cable which plugs straight into the Explore 64 board. We also have USB/serial converters based on other chipsets (see our website for the full listing).

Fig.4 shows how a CP2102-based converter is connected to the Explore 64 (other types should be similar). Note that the converter feeds through the 5V supply rail derived from the PC's USB port to power the Explore 64.

When the converter is plugged into your computer and the correct driver is installed, it will appear as a serial port (eg, COM3 in Windows). You then need to start a terminal emulator on your computer.

For Windows we recommend **Tera Term V4.88** which can be downloaded for free from http://tera-term.en.lo4d.com You will need to set its interface speed to 38,400 baud and connect it to the serial port created by the USB-to-serial converter.

Explore 64 Parts List

1 double-sided PCB, code 07108161, 72 x 27mm
1 tactile switch, 2-pin, surface-mount (S1)
1 20MHz crystal, low profile HC-49 (X1)
1 Mini USB type B socket (CON1) (Altronics P1308 or similar)
1 microSD card socket (CON3) (Altronics P5717 or similar)
2 40-pin or 50-pin male headers, 2.54mm pitch (JP1, CON2, CON4-6)
1 shorting block (JP1)

Semiconductors

1 PIC32MX470F512H-120/PT (120MHz) or PIC32MX470-F512H-I/PT (100MHz) 32-bit microcontroller programmed with 0710816A.hex (IC1)
1 MCP1703A(T)-3302E/DB low-dropout 3.3V regulator, SOT-223 (REG1)
1 MCP120(T)-270I/TT 2.7V supply supervisor, SOT-23 (IC2; optional – see text)
1 green SMD LED* (LED1)

Capacitors*

3 10µF 6.3V ceramic, X5R or X7R
7 100nF 50V ceramic, X5R or X7R
2 22pF ceramic, C0G/NP0

Resistors, 1% or 5%*

1 10kΩ 1 470Ω
1 1kΩ 1 10Ω

* Use SMD 3216 (1206 imperial) size; 2012/0805 or 1608/0603 sizes are also suitable but not recommended for beginners.

Where To Buy Parts

A kit for the Explore 64 is available from the SILICON CHIP Online Shop. This includes the PCB, a programmed PIC32 microcontroller and all other parts as listed above.

The PCB & programmed Micromite Plus microcontrollers are also each available separately.

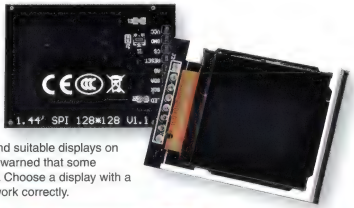
Also available are CP2102 USB-to-serial converters and 2.8-inch ILI9341 touchscreen displays (as used in the LCD Backpack).

PCBs, complete kits and fully assembled and tested Explore 64s are also available from Graeme Rixon (the designer of the PCB) – see www.rictech.nz/micromite-products

Supported LCD Panels

The Micromite Plus has built-in support for 10 different LCD panels, as follows:

1.44-inch ILI9163-Based Displays

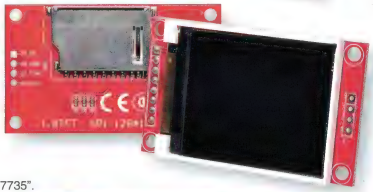


ILI9163-based displays use an SPI interface and have the following basic specifications:

- A 1.44-inch LCD.
- 128 x 128 pixels resolution.
- 25.5 x 26.5mm viewing area.
- Do not come with a touch controller.
- Do not have an SD card socket.

A typical ILI9163 based display is shown at right. You can find suitable displays on eBay by searching for the controller name, ie, "ILI9163". Be warned that some displays with a red PCB won't work with the Micromite Plus. Choose a display with a black PCB (as illustrated), as these have been tested and work correctly.

1.8-inch ST7735-Based Displays

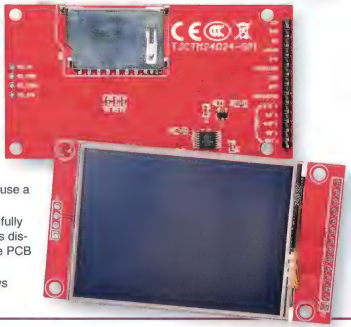


The ST7735-based displays also use a SPI interface and have the following basic specifications:

- A 1.8-inch LCD.
- 160 x 128 pixel resolution and a colour depth of 262K/65K.
- 38 x 35mm viewing area.
- Do not come with a touch controller.
- Have a full-size SD card socket.

You can find suitable displays on eBay by searching for "ST7735".

2.2 to 2.8-inch ILI9341-Based Displays



ILI9341-based displays use an SPI interface and have the following basic specifications:

- A 2.2, 2.4, 2.6 or 2.8-inch LCD.
- 320 x 240 pixel resolution and a colour depth of 262K/65K
- 43.5 x 35mm to 57.5 x 43mm viewing area.
- May have a touch controller (SPI interface).
- Have a full-size SD card socket.

The display that you purchase should look like the display shown at right, as there are other ILI9341-based displays which use a different interface and will not work with the Micromite.

In most cases, this display has a touch-sensitive facility which is fully supported by MMBasic. However, there are some versions of this display without the touch controller (the 16-pin IC on the back of the PCB at bottom right).

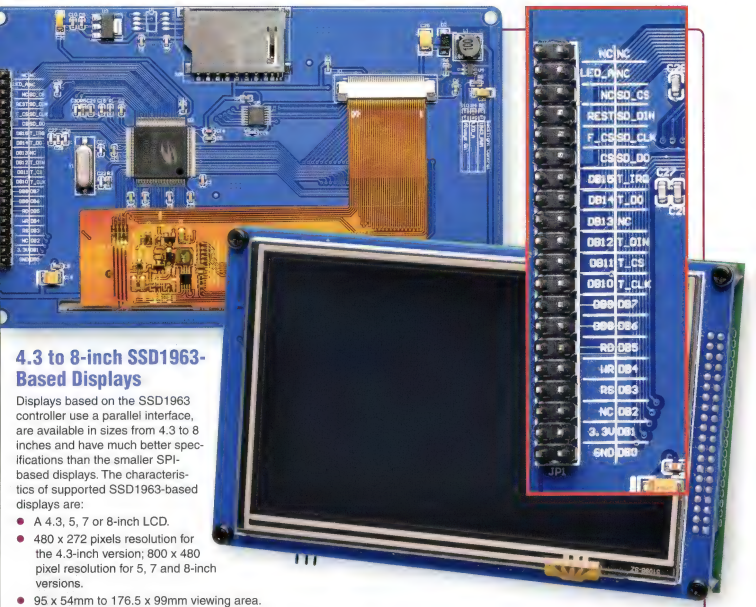
The standard Micromite also supports the ILI9341-based displays (both 28-pin and 44-pin versions).

Once that's been done, hit the Enter key in the terminal emulator and you should see the Micromite's command prompt (>). You can then enter, edit and run programs from this command prompt using nothing more than the PC's terminal emulator and the USB cable.

Testing

If you don't see the Micromite's prompt, something is definitely wrong and you will need to go through the following troubleshooting procedure.

The first step is to measure the current drawn by the Explore 64 from the 5V power supply. With nothing attached to its I/O pins, this should be



4.3 to 8-inch SSD1963-Based Displays

Displays based on the SSD1963 controller use a parallel interface, are available in sizes from 4.3 to 8 inches and have much better specifications than the smaller SPI-based displays. The characteristics of supported SSD1963-based displays are:

- A 4.3, 5, 7 or 8-inch LCD.
- 480 x 272 pixels resolution for the 4.3-inch version; 800 x 480 pixel resolution for 5, 7 and 8-inch versions.
- 95 x 54mm to 176.5 x 99mm viewing area.
- SSD1963 display controller with a parallel interface (8080 format).
- Have a touch controller (SPI interface).
- Have a full-sized SD card socket.

There are a number of different designs using the SSD1963 controller but fortunately **most Chinese suppliers have standardised on a single connector as illustrated in the photo at top right.** It is strongly recommended that any display purchased has this type of connector so that you can be reasonably confident that the manufacturer has followed the standard that the Micromite Plus is designed to use.

The 8-inch display supplied by the Chinese company EastRising uses a different connector layout to that shown, However, it has been tested with the Micromite Plus and works perfectly.

60-80mA. If it's substantially more or less than this, it indicates that something is wrong with either the soldering, the microcontroller or its power supply.

If this is the case, check that +3.3V is present on pins 10, 26, 38, 57 & 35 of IC1 and on various other components – see Fig.1. If this checks out, check that the capacitor connected to pin 56 (Vcap) of IC1 is correctly soldered and is the correct type; it must be a 10µF multi-layer ceramic type. A faulty capacitor will prevent the internal CPU from running and the current drain will be quite low (less than 10mA).

A disconnected pin can also prevent the micro from running so check the soldering on IC1's pins. It's easy to miss a pin and leave it floating just above its solder pad and without a decent magnifier and bright light, this may not be obvious.

Another cause of low current drain is either not programming the Micromite Plus firmware into the PIC32 chip or ignoring an error during this operation. Check that the micro has been correctly programmed.

If the current drain is about right, the next step is to attach the Explore 64's console to your computer or terminal emulator as shown in Fig.4. You could also try using the USB connector as the console but this is best left until last as it can involve some work

Fig.6: this is the display that you will see on the LCD when the command GUI TEST LCDPANEL is used. The display is animated with the circles being rapidly drawn on top of each other.

in installing the correct device driver and that would just confuse the testing process.

With the console connected, press the Reset button on the Explore 64 and you should see the start-up banner as shown in Fig.5. Note that you will not see this banner if you are using the USB console because resetting the Micromite Plus will also reset the USB interface.

If you don't see the start-up banner you should check the console Tx pin for some activity when the Reset button is pressed (this indicates that MMBasic is outputting its start-up banner). This can be done using a logic probe, oscilloscope or, at a pinch, a moving coil multimeter. If you do see some activity, the fault is probably either an incorrect console connection or is in the USB-to-serial converter.

User manuals

The Micromite Plus is quite an advanced device. After all, it is a full computer with a multitude of facilities. As a result, it has two user manuals which together add up to almost 150 pages.

The first manual is called the "Micromite User Manual" and it describes the features that are standard across the whole Micromite range, from the original 28-pin version to the 100-pin Micromite Plus (to be described in this magazine in the near future). The extra features of the Micromite Plus are described in the "Micromite Plus Addendum" which covers subjects such as the GUI functions, the SD card interface and other features that are only found in the Micromite Plus.

Both manuals are in PDF format and available for free download from the SILICON CHIP website. Before you build and test the Explore 64, it would be worthwhile downloading and looking through them as they provide a lot more information than we can fit into these pages.

Configuring an SD card

Once your Explore 64 is up and running, you can configure it to use an SD card. This occupies I/O pins 4, 5, 12, 14 & 47, ie, they can no longer be used as general purpose I/Os (GPIOs).

To set up the SD card, you need to use the **OPTION SDCARD** command. Note that this must be entered at the command prompt and can not be used in a program. The syntax is:

```
OPTION SDCARD CS-pin, CD-pin
```

where "CS-pin" is the I/O pin number that is used as chip select and "CD-pin" is the I/O pin number used for the card detect pin on the SD card connector.

This command only needs to be run once. When the Micromite is restarted, MMBasic will automatically initialise the SD card interface. If the SD card is no longer required, the command

```
OPTION SDCARD DISABLE
```

can be used which will disable the SD card and return the I/O pins for general use.

On the Explore 64, the SD card Chip Select (CS) signal is on pin 12 and the Card Detect (CD) signal is on pin 14. So, to enable the SD card you should enter the following command:

```
OPTION SDCARD 12, 14
```

To verify the configuration, you can use the command **OPTION LIST** to list all options that have been set, including the configuration of the SD card. As another test, you can pop an SD card into the slot and run the command **FILES**. This will list all the files and directories on the SD card.

Note that some SD cards can be temperamental and may not work so if you encounter a problem here, try a few SD cards before deciding that you have a fault. For example, some cards (especially high capacity, fast types) may demand more current than the power supply on the Explore 64 can provide.

USB interface

The USB interface on the Explore 64 doesn't need configuring. MMBasic monitors the interface and if it detects a host computer, it automatically configures it for serial emulation over USB.

A Windows-based host computer (versions before Windows 10) will require the installation of the "SILICON CHIP Serial Port Driver", which can be downloaded from the SILICON CHIP website. Macintosh and Linux based computers do not need a device driver, as support is built into the operating system.

Similarly, Windows 10 should not require any drivers to be installed.

Once configured, the USB interface works just like a serial port that's connected to the console. You can start up a terminal emulator such as "Tera Term for Windows" and tell it to connect to the virtual serial port created by the Micromite Plus.

Anything outputted by the Micromite Plus will be sent out on both the USB interface and the serial console. Similarly, anything received on either of these interfaces will be sent to MMBasic.

One benefit of using the USB interface as the console is that you can disable the serial console. This allows you to use the I/O pins allocated to the serial console for other duties, including use as a fourth serial I/O port. This is described further in the "Micromite Plus Addendum".

Configuring a display

As stated, MMBasic for the Micromite Plus has inbuilt support for 10 different LCD panels (1.44 to 8 inches). The smaller displays employ an SPI interface which uses only five I/O pins, so they are a good choice when you need a small display and want to keep as many I/O pins free as possible.

By contrast, the larger displays (4.3-8 inches) use an 8-bit parallel interface to transfer data. This requires 11 I/O pins but this is a small sacrifice considering the speed that it brings.

The full selection of supported displays is listed in an accompanying panel. Note that you do not have to use a display with the Explore 64; it is entirely optional and MMBasic will work perfectly well without one.

Having said that, using an LCD touchscreen is so simple and it adds such a professional air to a project that it is hard to think why you would not want to use one.

To configure the Micromite Plus for a particular LCD panel, use the **OPTION LCDPANEL** command. This comes in two forms. Displays with an SPI interface use this form:

```
OPTION LCDPANEL controller, orientation, D/C pin, reset pin [, CS pin]
```

While displays that have a parallel interface use this form:

```
OPTION LCDPANEL controller, orientation [, LCD-A pin]
```

The "controller" parameter defines what type of display controller chip is used on the display. This can be one of:

- **ILI9163:** a 1.44-inch display with an ILI9163 controller.
- **ST7735:** a 1.8-inch display with an ST7735 controller.
- **ILI9341:** A 2.2, 2.4, 2.6 or 2.8-inch 240 x 320 pixel display with an ILI-9341 controller.
- **SSD1963_4:** a 4.3-inch display with an SSD1963 controller.
- **SSD1963_5:** a 5-inch display with an SSD1963 controller.
- **SSD1963_5A:** an alternative version of the 5-inch display if SSD1963_5 doesn't work.
- **SSD1963_7:** a 7-inch display with an SSD1963 controller.
- **SSD1963_7A:** an alternative version of the 7-inch display if SSD1963 7 doesn't work.
- **SSD1963_8:** an 8-inch display supplied by the Chinese company East-Rising (www.buydisplay.com).

The "orientation" parameter specifies the normal position of the display which might be mounted in a portrait orientation or even upside-down. Your choices for this parameter are **LANDSCAPE**, **PORTRAIT**, **RLANDSCAPE** or **RPORTRAIT**. These can be abbreviated to **L**, **P**, **RL** or **RP**. The **R** prefix indicates the reverse or "upside down" orientation.

The remaining parameters in the command specify some of the I/O pins used for the display. There are other pins that are dedicated when you specify a type of display as listed the "Micromite Plus Addendum". This specifies exactly how to connect a display and what I/O pins to use.

To test the display, enter the command:

```
GUI TEST LCDPANEL
```

You should immediately see an animated display of colour circles being rapidly drawn on top of each other (Fig.6). Pressing the space bar on the console's keyboard stops the test.

When using an LCD panel that has an SSD1963 controller, the Micromite Plus can display 800x480 pixels in true (24 bit) colour. This image of a tiger demonstrates the resolution and colour range.

Configuring touch

Most displays are supplied with a resistive touch-sensitive panel and its associated controller chip. To use the touch feature in MMBasic, the touch controller must first be connected to the Micromite Plus and then configured. The connections for the touch controller are different on each LCD panel, so refer to the "Micromite Plus Addendum" for the details.

MMBasic is configured for touch using the **OPTION TOUCH** command at the command prompt (not in a program). This should be done after the LCD panel has been configured. The syntax is:

```
OPTION TOUCH T_CS pin, T_IRQ pin [, click_pin]
```

where **T_CS pin** and **T_IRQ pin** are the Micromite I/O pins to be used for chip select and touch interrupt respectively (any free pins can be used).

The "click_pin" parameter is optional and specifies an I/O pin that will be driven briefly high when a screen control is touched. This can be used to drive a small piezo buzzer which will produce a click sound, thereby providing an audible feedback whenever a GUI element on the screen is activated. We will cover this subject in detail in a future article, where we describe the on-screen graphic (GUI) controls.

As with other options, this command only needs to be run once and every time the Micromite is restarted, MMBasic will automatically initialise the touch controller. If the touch facility is no longer required, the command **OPTION TOUCH DISABLE** can be used to disable the touch feature and return the I/O pins for general use.

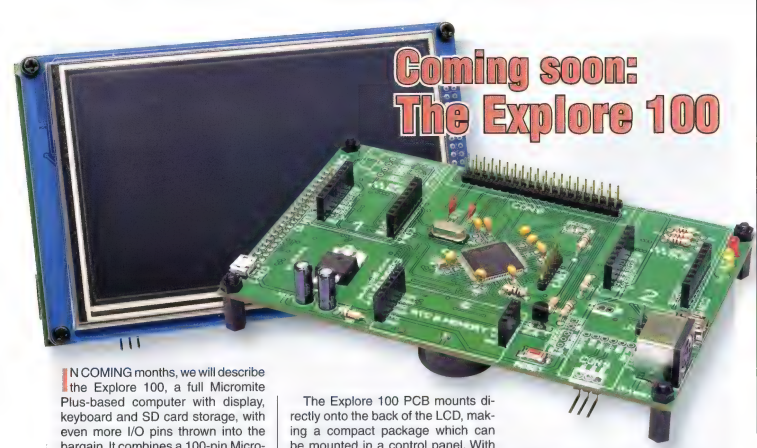
Before the touch facility can be used, it must be calibrated using the **GUI CALIBRATE** command. The calibration processes starts with MMBasic displaying

Firmware Updates

For firmware updates and other information relating to the Micromite Plus, check the author's website at geoffg.net/micromite.html

Firmware updates will also be made available for download from the SILICON CHIP website as soon as we have been notified.

Coming soon: The Explore 100



IN COMING months, we will describe the Explore 100, a full Micromite Plus-based computer with display, keyboard and SD card storage, with even more I/O pins thrown into the bargain. It combines a 100-pin Micromite Plus with a 5-inch touch-sensitive LCD panel to make a powerful integrated computer or controller with a multitude of uses.

The Explore 100 PCB mounts directly onto the back of the LCD, making a compact package which can be mounted in a control panel. With stunning graphics and plenty of input/output lines, the Explore 100 is ideal for controlling anything from a home-built lathe to an industrial process. You could also use it to write games or to control a telescope, or you might just want to play with a powerful BASIC computer.

a target in the top-left corner of the screen. A blunt pointed object such as a stylus is then pressed exactly on the centre of the target and held down for at least one second. MMBasic will record this location and then continue the calibration by sequentially displaying the target in the other three corners of the screen.

Following calibration, you can test the touch facility using the **GUI TEST** **TOUCH** command which will blank the screen and wait for a touch. When the screen is touched with a stylus, a white dot will appear on the display. If the calibration was carried out successfully, this dot will be displayed exactly under the location of the stylus.

Pressing the space bar on the console's keyboard exits the test routine.

Acknowledgements

My thanks to Graeme Rixon who designed the Explore 64 PCB and helped with its development. Graeme can supply bare PCBs, parts and the fully assembled and tested Explore 64s – see the parts list for details.

My thanks also to the many members of the Back Shed forum who acted as beta testers during the Micromite Plus' long development. The forum also has many members who are happy to help newcomers to the Micromite series. You can find it at thebackshed.com/forum/Microcontrollers

Touch functions

It's easy to use the touch interface with MMBasic. There are eight functions that provide useful information, as follows:

TOUCH(X) – returns the X coordinate of the currently touched location.

TOUCH(Y) – returns the Y coordinate of the currently touched location.

TOUCH(DOWN) – returns true if the screen is currently being touched (this is much faster than **TOUCH(X)** or **TOUCH(Y)**).

TOUCH(UP) – returns true if the screen is currently NOT being touched (also faster than **TOUCH(X)** or **TOUCH(Y)**).

TOUCH(LASTX) – returns the X coordinate of the last location that was touched.

TOUCH(LASTY) – returns the Y coordinate of the last location that was touched.

TOUCH(REF) – returns the reference number of the control that is currently being touched or zero if no control is being touched. We will cover this subject in depth in a future article.

TOUCH(LASTREF) – returns the reference number of the control that was last touched.

You can also set up an interrupt subroutine to be called when the screen is touched or touch is removed. A touch interrupt is important when you are using the GUI controls.

These powerful functions make employing the Micromite Plus as a controller a dream and we will cover them in more detail in a future article.

That's all for now. In coming months, we will present the Explore 100, which can be mounted on the back of a 5-inch display to make a complete controller or self-contained computer. SC

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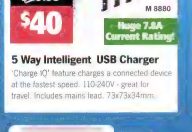

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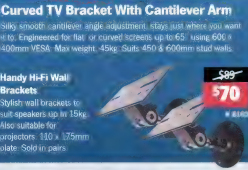

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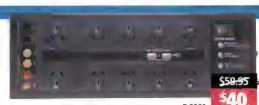

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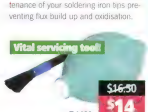

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B 0092

Add a 7-inch touchscreen to your Raspberry Pi

By Greg Swain

If you want to turn your Raspberry Pi (RPi) into a completely self-contained unit, then this 7-inch (18cm) Touchscreen Display is the answer. It's a cinch to hook-up and get going, has a bright 800 x 480 pixel display and includes a mounting kit so that you can attach the RPi module to the display's metal back-plate.

YOU MIGHT think that adding a touchscreen display to your Raspberry Pi (RPi) would be complicated but it's not. Basically, it's just a matter of plugging two captive flat-ribbon cables from the display into the supplied adaptor board, connecting a separate flat ribbon cable between the adaptor board and the RPi's DSI (digital serial interface) socket, adding a couple of power supply leads and that's it.

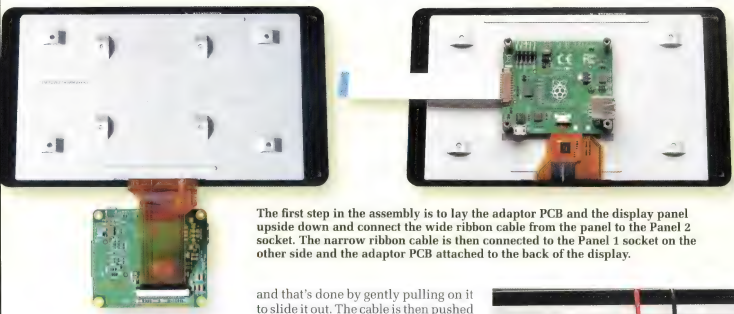
There's no software (apart from operating system updates) to add and it should all start working the moment you apply power to boot the RPi. You can add a virtual keyboard if you wish but more on that later.

What's in the kit

As well as the 7-inch Touchscreen Display and the aforementioned adaptor (or driver) board, the kit includes the DSI ribbon cable, four M2 x 12mm spacers, four M2 screws and four jumper wires. Only two jumper wires (for the power supply) are required for later RPi models (Model A+, B+, RPi2 & RP3) but the early Model A and Model B boards require the remaining two jumpers to be added (see below).

No instructions are supplied with the kit but there's lots of assembly information online, including on the element14 website – see www.element14.com/community/docs/DOC-78156/l/raspberry-pi-7-touchscreen-display

There's also an excellent video of the assembly process here: https://www.



The first step in the assembly is to lay the adaptor PCB and the display panel upside down and connect the wide ribbon cable from the panel to the Panel 2 socket. The narrow ribbon cable is then connected to the Panel 1 socket on the other side and the adaptor PCB attached to the back of the display.

raspberrypi.org/blog/the-eagerly-awaited-raspberry-pi-display/

Update the software

The latest versions of Raspbian include all the software and drivers necessary to operate the Touchscreen Display. For this reason, it's a good idea to update your RPi's operating system before attaching the unit.

To do this, make sure your RPi is connected to the internet, then SSH or VNC into your RPi (or connect it to a keyboard, mouse and monitor), open a command window and type:

```
sudo apt-get update
```

Once the updates have downloaded, do the following:

```
sudo apt-get upgrade
sudo reboot
```

This will install all the latest drivers and software necessary to support the 7-Inch Touchscreen Display.

While you are at it, you may as well install the virtual keyboard, as follows:

```
sudo apt-get install matchbox-keyboard
sudo reboot
```

Hardware assembly

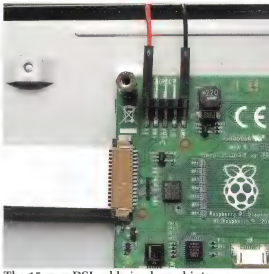
The first step in the assembly is to lay both the adaptor board and the display upside down and plug the wide ribbon cable from the display into the Panel 2 socket. For the uninitiated, it's not just a matter of pushing the cable into the socket though. Instead, you first have to release the little plastic locking bar and that's done by gently pulling on it to slide it out. The cable is then pushed into the socket and secured by sliding the locking bar back in.

Once that's done, the adaptor board is flipped over, laid on the back of the display and the narrow ribbon cable plugged into the Panel 1 socket. As before, it's secured using a locking bar after making sure that the cable has been pushed all the way into the socket.

By the way, the touchscreen LCD is supplied with a protective plastic film. This should be left in place during the assembly to prevent scratches.

The next step is to attach the adaptor board to the back of the display using the four M2 x 12mm spacers. The DSI cable is then plugged into its socket (silver contacts facing up) and the red and black jumper cables plugged into the +5V and GND pins on the adjacent connector (see photo).

After that, it's just a matter of securing the RPi module to the spacers using the four M2 screws, connecting the DSI cable (silver contacts facing inwards) to its DSI socket and plugging in the red & black supply cables into pin 2 (+5V) and pin 6 (GND) on the RPi's GPIO port.



The 15-way DSI cable is plugged into its socket on the driver PCB with its contacts facing up. This close-up view also shows the 5V supply output leads which run to pins 2 & 6 on the RPi's GPIO header.

RPi Models A & B

RPi Model A/B modules don't have the required I²C outputs on the DSI bus to communicate with the driver board. The way around this is to use the two extra jumper wires provided to connect the SDA and SCL pins on the adaptor board's GPIO header to SDA (pin 3) and SCL (pin 5) respectively on the RPi's GPIO header.

Use the green wire to connect from SDA on the adaptor board to pin 3 on the RPi's GPIO header. The yellow wire is then connected from SCL on the adaptor board to pin 5 on the RPi's GPIO header. Note that these connections are NOT required on later model RPi modules (A+, B+ Pi2 or Pi3).

There's one more step here: by default, DSI display detection is disabled on early A/B RPi boards, so it has to be enabled at boot time. To do this, SSH or VNC into your RPi and add the following line to **/boot/config.txt**:

```
ignore_lcd=0
```

Power supply

You need to use a 5V DC plugpack rated at 2A to power both the display

The RPi module mounts on top of the spacers and the DSI cable and supply leads connected to complete the assembly. Note that the supply cables have been left disconnected here so that the adaptor board and the RPi module could be powered from separate plugpacks – see text.

and the RPi. This should be plugged into the PWR IN micro-USB socket on the adaptor board. **DO NOT use the RPi's micro-USB port; the display consumes around 400mA and you could exceed the maximum current rating of the RPi's polyfuse if you do.**

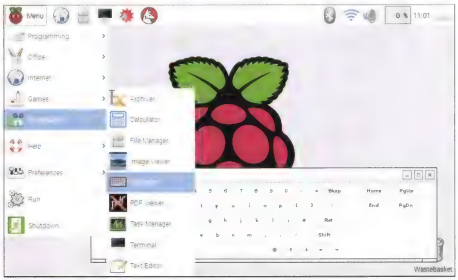
The adaptor board supplies 5V power to the RPi via the jumper cables plugged into the latter's GPIO port (pins 2 & 6). Alternatively, you can delete these jumper wires and connect a USB-to-micro-USB cable between the adaptor board's PWR OUT socket and the RPi's PWR IN socket.

Yet another possibility is to power the display and the RPi from two separate plugpacks (ie, delete the jumper wires or USB cable).

Booting up

When you boot the RPi, it will automatically detect the Touchscreen Display and use that as the default. The display should begin working as soon as power is applied and once the RPi has booted, you should have full touchscreen operation.

If it doesn't work, check that all the cables have been properly seated in their sockets. Check also that the power supply is rated at 2A if using it to power both the display and the RPi.



The virtual keyboard is easy to install (see text) and is accessed by tapping Menu –> Accessories –> Keyboard. It makes it easy to enter web addresses and to edit files, etc without having to connect an external keyboard or to access the RPi via VNC from another computer.

Default monitor

Because the Touchscreen Display is now the default, this his means that if a monitor is also plugged into the RPi's HDMI port, it will be ignored. If you want to keep an HDMI monitor as the default, just add

```
display_default_lcd=0
```

to the **/boot/config.txt** file. It's also possible to use both display outputs at the same time – see https://www.raspberrypi.org/blog/the-eagerly-awaited-raspberry-pi-display/

Using the virtual keyboard

Touching **Menu –> Accessories –> Keyboard** brings up the virtual keyboard as shown in the screen grab at left. You can elect to always have this keyboard above other open windows by clicking on the keyboard symbol at

Compatibility Issues Between Raspberry Pi Touchscreen & GPIO port

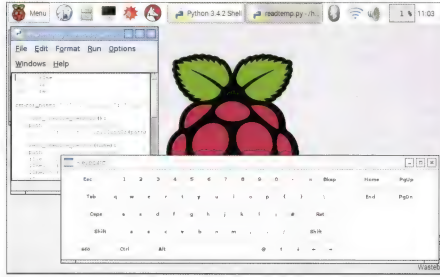
When testing this screen, we discovered that the Raspberry Pi has some problems accessing the GPIO pins while the touchscreen is plugged in. Pins 3 & 5 on the GPIO port are shared with pins 13 & 14 on the display connector. These pins form an I²C serial bus and are labelled SDA0 and SCL0.

Basically, this means that if you try to use pins 3 & 5 on the GPIO connector for any other purpose, the touchscreen will go blank and refuse to work. Unfortunately, the software that we used to set up outputs #1 and #2 for the "4-Input Temperature Sensor PCB For The Raspberry Pi" (May 2016) did just that.

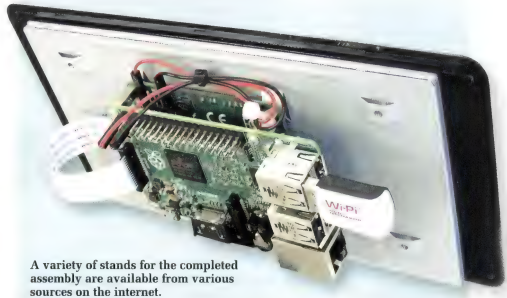
In order to get the screen to work, we had to delete (or rename) the **dt-blob.bin** file that's installed in the RPi's **/boot** folder, as described in May 2016. In addition, we had to comment out the line that we had added to **/etc/rc.local** (ie, the line beginning with "python").

As a result, you will no longer be able to set outputs #1 and #2 at boot, although outputs #3 and #4 can still be used, as described in the May 2016 issue. The DS18B20 temperature sensors can also still be used as normal with the touchscreen connected, as described in Silicon Chip for March & May 2016.

Updated software scripts archived in **RPiTempMonV2.zip** are available on the Silicon Chip website. Do not install **dt-blob.bin** but edit **/etc/.rc.local** as before.



The virtual keyboard can be resized and can also be configured so that it always sits on top of other open windows (just click the keyboard symbol at top left of its window and select Layer –> Always On Top).



A variety of stands for the completed assembly are available from various sources on the internet.

top, left of the keyboard window, then selecting **Layer –> Always On Top**.

Display stand

To be of real use, the assembly needs some kind of case or stand and there are several that can be purchased online. For example, element14 have a full enclosure at http://au.element14.com/multicomp/cbrpp-ts-blk-wht/raspberry-pi-touchscreen-enclosure/dp/2494691 Another case and stand is at www.modmypi.com/raspberry-pi/cases/7-touchscreen-cases/raspberry-pi-7-touchscreen-case-plus-stand

Alternatively, take a look at the Pimoroni website at https://shop.pimoroni.com/products/raspberry-pi-7-touchscreen-display-with-frame They have a very attractive transparent acrylic stand which is available in six different shades: orange, red, green, blue, purple and black. A Pimoroni case is also available from Core Electronics – see http://core-electronics.com.au/pimoroni-raspberry-pi-7-touchscreen-display-case-noir.html

Yet another very attractive stand is at https://www.adafruit.com/product/2033 It's just $US14.95 (plus shipping).

Rotating the display

Depending on the stand or enclosure that's chosen, you might find that the display is upside-down when the panel is in position. If so, simply add

```
lcd_rotate=2
```

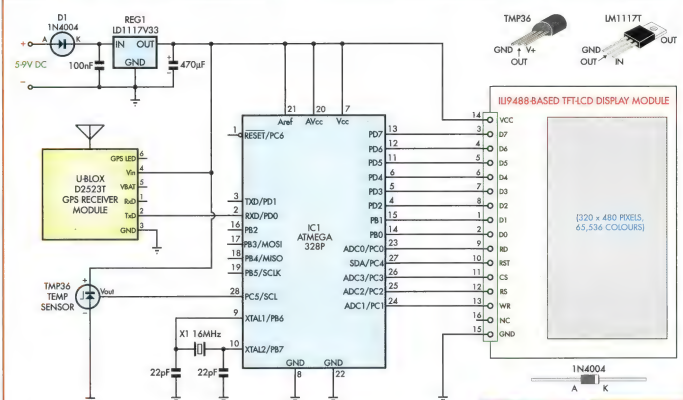
to **/boot/config.txt** then reboot the RPi and you won't have to stand on your head any longer. SC

Where To Buy The Touchscreen Display

The RPi 7-Inch Touchscreen Display can be purchased from Altronics, Wiltronics Research and element14. Check their respective websites for further details.

CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions will be paid for at standard rates. All submissions should include full name, address & phone number.



Arduino-based Analog & Digital LCD Clock

This project bears some similarity to the Micromite Touchscreen Super Clock published in the July 2016 issue. However, instead of the Micromite, it uses an ATmega328P processor, the same chip used in the Arduino Uno and the software was developed using the Arduino integrated development environment (IDE). It uses a somewhat larger LCD than the Super Clock, nearly four inches diagonal compared to the 2.8-inch screen in the Super Clock.

The circuit is quite simple and besides the microcontroller and TFT LCD module, comprises a GPS receiver for accurate timekeeping, temperature sensor (so the clock can display ambient temperature), crystal and load capacitors for the micro's own clock and a simple linear power supply with a 3.3V low-dropout regulator, input and output capacitors and a reverse polarity protection diode.

The LCD has a 480 x 320 pixel resolution and costs around $US8 on Ali Express – see www.aliexpress.com/item/Free-shipping-LCD-module-TFT-3-95-inch-TFT-LCD-screen-for-Arduino-MEGA2560-Board/32648492743.html

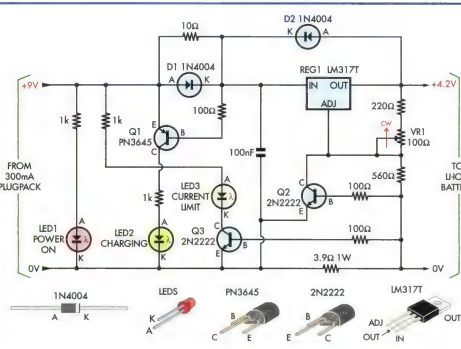
The prototype is shown in the adjacent photo and as you can see, it has a digital time and date read-out in the upper-right corner of the screen, with the temperature below (in °C) and an analog clock display with second hand filling the left-hand side of the screen. You can see a short video of the clock in operation at www.siliconchip.com.au/Videos/Arduino-based+Analog+and+Digital+Clock

The TMP36 temperature sensor has an output voltage proportional to temperature and this is read using IC1's internal ADC, via pin 28 which is also ADC input #5. GPS data is received in RS-232 TTL format at the RXD pin (pin 2).

The LCD is driven using an 8-bit parallel interface, along with the RD (read), WR (write), RS (register select), CS (chip select) and RST (reset) control pins. The software makes use of the MCUFRIEND Arduino LCD library and AdaFruit graphics library, which are both included in the software download package.

Most of the complexity of this design is hidden in the software (*arduino_half_square_clock_with_design.ino*) which is available for download from the SILICON CHIP website, so if you are interested in the details of how it works, you can read through the sketch. Even if you aren't interested in building this clock, the code can also serve as a good example of how to drive this type of display from an Arduino and also how to receive data from a GPS module.

Somnath Bera,
Vindhyanagar, India. ($75)



Simple Li-Ion Cell Charger

This circuit uses an LM317T adjustable 3-terminal regulator to provide a simple current-limited charger for Li-ion cells. LED indicators are provided for power indication, charging and current limiting. It runs from a 9V DC plugpack.

The 220Ω/560Ω voltage divider at the output of REG1 sets the output voltage to about 4.2V, with VR1 allowing the charge termination/open circuit output voltage to be accurately set to anywhere between 3.6V and 4.25V. Most 3.7V Li-ion and Li-po cells will normally specify a full charge voltage between 4.1V and 4.2V.

Red LED1 provides power-on indication, while green LED2 indicates charging and is extinguished at completion of the charge (ie, when the current drawn from the output is very low). Yellow LED3 indicates when current limiting is in effect.

When current is drawn from the output, it flows through D1, creating a voltage drop of about 0.6-0.8V, depending on how much current is flowing. Above a certain threshold, this is sufficient to forward bias Q1's base-emitter junction, turning the green LED on. As the cell charges and its voltage increases, the charging current falls off, reducing the voltage drop across D1. When the voltage falls sufficiently, Q1 turns off and so does the green LED.

Over-current control is provided by Q2, its 100Ω base resistor and the 3.9Ω 1W current-sense resistor. Return charge current from the cell's negative terminal flows through this 3.9Ω resistor to ground, forming a voltage drop of 3.9V/A or 1V at 256mA. When this is sufficient to forward-bias the base-emitter junction of Q2, it turns on, pulling REG1's adjust terminal towards the negative supply. This lowers its output voltage and hence current and when at the minimum of about 1.25V, the current is limited to around 300mA.

When Q2 is switched on, so is the identically-connected Q3, lighting LED3 (yellow). Diode D2 protects the LM317 in the event that the supply is disconnected while charging.

Phillip Webb,
Hope Valley, SA. ($60)

Auto-ranging 10μA to 10A Current Meter

I often find that I want to monitor supply current to a project I am working on but I need my multimeters for probing the circuit, monitoring supply voltages, etc. Also when measuring current, it's quite easy to blow the meter's fuse or destroy its internal shunt due to excessive current. Hence, I designed this 10μA-10A auto-ranging meter that automatically cuts out if the current exceeds 10.2A.

The design criteria included easy calibration and high accuracy. It's microprocessor controlled and its result is displayed on a standard LCD.

The microprocessor senses the shunt voltage and switches in an appropriate shunt value using Mosfets Q1-Q6 as electronic switches, to select the best range for the measurement being made. As the voltage across the shunt is small, a DC amplifier is placed between the selected shunt and the microcontroller's ADC input.

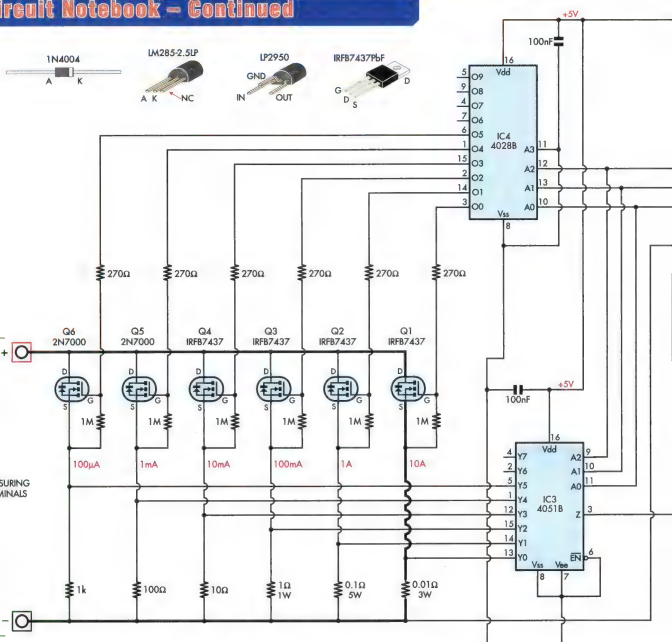
To enable reasonable tolerance shunt resistors to be employed, electronic switching is used to select a different amplifier gain potentiometer for each range, allowing calibration of each shunt. Placing the shunt between the source of the FET and earth removes the FET's on-resistance from the measurement. However, low on-resistance FETs are still desirable to minimise dissipation. The specified FET for the 10A range has an on-resistance of about 2mΩ, for a maximum dissipation of 200mW, so no heatsinking is needed.

REF1, an LM285Z-2.5V provides the reference voltage for the ADC on pin 2 of PIC16F88 microprocessor IC5. The ADC is a 10-bit type so it can sense 2^{10} or 1024 discrete voltages between 0 and 2.5 V. If we make 1000 the upper limit of each range, the maximum voltage needed on pin 3 (the ADC input) is 1000 ÷ 1023 x 2.5V = 2.44V.

The shunt used for the 10A range is 0.01Ω which gives a voltage of 10A x 0.01V = 0.1V for a full-scale reading. Similarly, the shunt for the 1A range is 0.1Ω which gives the same result and so on. So the amplifier needs a gain of 2.44V ÷ 0.1V = 24.4 times. We use an OPA4344 quad CMOS rail-to-rail op amp (IC1), with each stage cascaded.

Because of the high gain, any mains pick-up (50Hz, 100Hz, etc) will affect the result. So we use a low-pass filter with a cut-off below

continued on page 86



50Hz to attenuate any mains interference. This filter is combined with the gain stages in IC1c and IC1d. The -3dB point of the filter is 16Hz and the roll-off is approximately 84dB/octave.

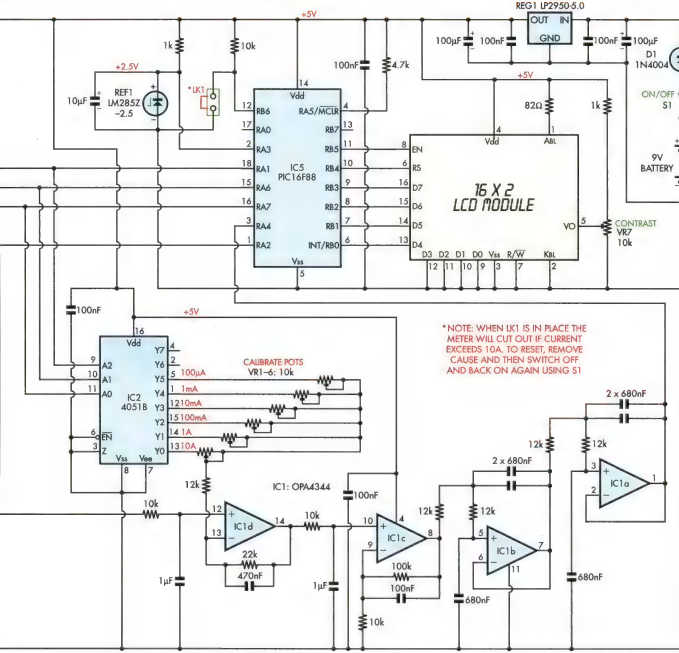
Op amps IC1a & IC1b form a unity-gain active filter with a -3dB point of 13.8Hz. The preceding stage, built around IC1c, provides a gain of 11, as determined by the ratio of the 100kΩ and 10kΩ feedback resistors. It's also set up to provide low-pass filtering with a 100nF capacitor across its feedback resistor and a low-pass filter (10kΩ/1µF) at its pin 10 non-inverting input.

Its input is driven by the preceding stage, built around IC1d, which has a gain of around 2.22, set by the 22kΩ and 12kΩ feedback resistors plus 10kΩ gain adjust trimpot VR6. With VR6 set correctly, the overall gain becomes the desired 24.4 times. IC1d also performs further low-pass filtering, in a similar manner to IC1c.

Depending on which range is being used, 8:1 analog switch IC2 (a 4051B) connects the appropriate trimpot to ground, activating it. IC5 selects the pot using address lines A0-A2 (pin 11-9). A second 4051B, IC3, connects the positive end of the appropriate shunt to the pin 12 non-inverting input of amplifier IC1d via a 10kΩ protection resistor.

At the same time, BCD-to-decimal decoder IC4 (4028B) drives the gate of the appropriate Mosfet (Q1-Q6) high so that current though the measurement terminals flows through the required shunt only. The other Mosfet gates are driven low to switch them off and a 1MΩ resistor between each gate and source keep them off when the unit is powered down.

As well as driving outputs RA1, RA6 and RA7 of IC5 (pins 18, 15 & 16) to select the appropriate measurement range, the microcontroller software constantly performs the analog-to-digital conversions for the measurement voltage present at pin 3, computes the current value, adds the appropriate units and displays this on a two-line alphanumeric



LCD. VR7 provides contrast adjustment.

If LK1 is inserted and a current measurement above 10.2A is registered, IC5 will immediately switch all the Mosfets (Q1-Q6) off, disconnecting the load and protecting the circuit. It's reset by removing the overload condition and power cycling the unit using switch S1.

The meter is powered from a 9V battery. Current flows to micropower low-dropout 5V regulator REG1 via reverse polarity protection diode D1. It can operate down to a battery voltage as low as 6.7V.

To calibrate the unit, connect an accurate ammeter in series with a dummy load and the test terminals, then apply voltage to get a reading of around 8A. Adjust VR6 until the reading on the meter matches that on the reference ammeter. Now increase the dummy load to reduce the current to around 0.8A, then adjust VR5 and continue the procedure until all six ranges have been calibrated.

Note that the required dummy load for the 10A range will be around 1Ω and will need to be rated to dissipate at least 100W. If you have a bench supply, you can use a much lower voltage and thus lower-value dummy resistance with a lesser power rating.

IC1, REF1 and Q1-Q4 are available from element14. The rest of the parts can be bought at Jaycar.

The software (*Autorange Ammeter3.BAS*) is written in PICBasic Pro and the BASIC source code and HEX file are available for download from the SILICON CHIP website.

Les Kerr,
Ashby, NSW ($90)

Circuit Ideas Wanted

Got an interesting original circuit that you have cleverly devised? We need it and will pay good money to feature it in the Circuit Notebook pages. We can pay you by electronic funds transfer, cheque (what are they?) or direct to your PayPal account. Or you can use the funds to purchase anything from the SILICON CHIP on-line shop, including PCBs and components, back issues, subscriptions or whatever. Email your circuit and descriptive text to editor@siliconchip.com.au

Review by
Ross Tester

All singing, All dancing . . .

Tecsun's S-2000 Multiband Radio

After seeing the reader review of the tiny Tecsun PL365 Multiband Radio in the June issue of SILICON CHIP, Tecsun Radios Australia asked us if we'd like to review the "flagship" Tecsun, the S-2000 Desktop Radio. Knowing how much our readers are still interested in performance radios (you tell us!), of course we said YES!

Despite the growth of internet radio, where you can "tune in" to virtually any radio station in the world on your computer in crystal clarity, the somewhat dying "art" of using a communications receiver to actually resolve faint, almost non-existent radio signals from the other side of the world still has a fascination for many.

Of course, with city living, a lot of readers are often compromised by their surroundings when it comes to erecting "decent" antennas but that doesn't stop them from trying. But then you need a similarly "decent" receiver.

Having grown up in the days of large valve receivers with limited shortwave bands and limited bandspread (absolutely zero bandspread when it came to amateur bands!), I spent countless hours "twiddling the dial", looking for both long distance AM broadcast stations and overseas shortwave stations – to this end I was forever erecting higher and longer antennas.

I even worked out that tuning another receiver close to

the one I was listening to would even allow me to listen in to "duck talk" (which I found out much later was SSB and I was "resolving" the signal, albeit crudely!).

Fortunately, being a "boy from the bush" with accommodating, if somewhat bemused, neighbours, I had quite an advantage over my city cousins.

I recall my last antenna stretched over three backyards and ended secured near the top of what must have been a mile-high poplar tree. OK, I'm exaggerating that just a tad but it was [to a 12-year-old] rooly, rooly high, particularly when I had to climb that tree to place the wire and then [regularly!] to repair breaks.

I digress somewhat – just to reinforce the fact that I had enormous listening pleasure with that old valve receiver, logging both commercial and even amateur radio stations on every continent (except Antarctica!).

It did wonders for my geography classes at school, too: how many other kids knew that Quito was the capital of Equador? (It was also the home of HCJB, "The Voice of the Andes").

You can imagine my unbridled joy a decade or so later when I managed to get my hands on the (now) venerable Yaesu FRG-7 communications receiver (known affectionately as "The Frog").

Sure, there were many others (does anyone remember the Collins, Heathkit, Hallicrafters, Kenwood, Geloso and so on?) but in Australia, at least, The Frog was The King!

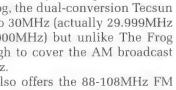
To give you some idea of their reputation, even today you can expect to pay over $500 for a good Frog on ebay (if you can find one!).

Enter the S-2000

I mention The Frog because this triple-conversion, Wadley-loop receiver really was the yardstick by which all receivers at the time were compared. And it's not too dissimilar in size to the Tecsun S-2000 – about the same width and height but about double the depth. It was also a LOT heavier – more than double the Tecsun's weight.

And while its performance as a communications receiver is still "right up there", the amount of features pale into insignificance when you look at today's PLL (phase-locked-loop) receivers. Like The Frog, the dual-conversion Tecsun S-2000 offers reception up to 30MHz (actually 29.999MHz whereas The Frog was 29.900MHz) but unlike The Frog (which just went low enough to cover the AM broadcast band), it starts at just 100kHz.

In addition, the S-2000 also offers the 88-108MHz FM broadcast band (in stereo if you use headphones!) along with the 118-137MHz aircraft band.



At left is the external antenna connection panel, offering 50Ω for FM and shortwave and 500Ω for AM and shortwave. Above is the stereo (for FM) line out socket and somewhat unusually, a 455kHz AM IF output socket for an external decoder (eg, DRM).

Tecsun S-2000 Performance & Features

- Bands: MW 522-1620 kHz (9kHz Tuning Step)
  LW 100-519 kHz
  SW 1711-29999 kHz
  AIR 118-137 MHz
  FM 87-108 MHz (FM stereo via 'phones)
- Sensitivity: LW – less than 3mV/m (S/N 26dB)
  MW – less than 0.35mV/m (S/N 26dB)
  SW – less than 18μV (S/N 26dB)
  SSB – less than 1μV (S/N 10dB)
  AIR – less than 5μV (S/N 10dB)
  FM – less than 3μV (S/N 30dB)
- Selectivity: Wideband AM (±10kHz) – Greater than 40dB
  Narrowband AM (±5kHz) – Greater than 60dB
- Image Rejection:
  MW,LW,SW: 55.845MHz (1st IF): Greater than 90dB
  455kHz (2nd IF): Greater than 80dB
  AIR: Greater than 90dB
  FM: Greater than 60dB
- IF Rejection:
  AM: 55.845MHz (1st IF): Greater than 60dB
  455kHz: Greater than 60dB
  FM: 10.7MHz: Greater than 100dB
- AGC: Range wider than 80dB (threshold 12μV)
- Dual conversion for LW, MW & SW
- Single side band (SSB) with USB & LSB
- Auto/manual frequency tuning or station memory tuning or direct frequency key-in function
- Auto suning storage (ATS) function for FM / MW & LW (5s pre-listening while auto tuning)
- 1000 station memories (100 each for FM, SW, SSB & air band; 50 each for MW & LW; 500 for mixed band)
- 24 hour clock and dual alarm clock function (alarm by either radio or buzzer)
- Sleep timer function
- Extra-long telescopic whip antenna for FM, SW, Air Band.
- 360° rotating MW antenna
- External or internal FM/MW antenna switch
- Antenna attenuation to enhance reception.
- Squelch control.
- Wide/narrow bandwidth selection
- RF gain control.
- 455kHz IF output jack (for synchronous detection, DSP demodulator, DRM converter, etc)
- High quality built-in 4-inch speaker
- Line in socket (can be used as speaker for MP3)
- Line out socket (radio broadcast can be transferred to amplifier, recorder, etc)
- Power sources: 4 x "D" alkaline batteries
  230VAC power
  6V DC jack (@ 350mA maximum)
- Dimensions: 372 x 183 x 153mm (w x h x d)
- Weight: 2.7kg
- Price: $425.00 including GST

I can't recall how many station memories The Frog offered but the Tecsun has 1000 – yes, *one thousand* – 100 each for FM, SW, SSB and Air band; 50 each for MW and LW and 500 for mixed band.

You can automatically or manually store stations as you find them and sort them later as you wish.

OK, let's stop making comparisons because they aren't really fair – The Frog was made in the late 1970s/early 1980s and electronics have come a long way since then.

Instead, have a look at the Specifications Panel and you'll see just how advanced the S-2000 really is!

OK, what's it offer?

We've already looked at the modes of operation and frequencies. What we should add here is that it also has a 455kHz IF AM output socket for other (external) decoders, such as DRM (should we ever see it in Australia – but you can tune in DRM from over the ditch!).

It also sports line-out for external amplifiers (300mV, 4.7kΩ), with stereo sockets for FM broadcasts, an 8-32Ω stereo headphone/earphone socket and also an audio line-in.

As far as antenna inputs go, along with the inbuilt, rotatable ferrite rod antenna on the top of the set (which we'll look at shortly) it also has a rather longer than "normal" whip antenna (the specs say 1200mm; we measured 1000mm) for FM and air band. If you want to use an external antenna (and who wouldn't on a receiver such as this?) you have the choice of 50Ω BNC inputs for FM, air band and SW or 500Ω (long-wire) input for shortwave and AM. A slider switch selects either internal or external antenna.

Power is either 230VAC from an inbuilt cord, nicely stored in a compartment at the rear, 6V DC (@ 350mA) via an external adaptor or 4 x "D" size batteries (preferably alkaline). We've seen mention of using 4 x "AA" size but without an adaptor, this would not be practical. In fact, we wouldn't go this route (even if we could find an adaptor) because the smaller cells would have a significantly shorter life.

Controls

The Tecsun S-2000 offers so many front panel controls that you could be confused at first but they're all pretty logical and a couple of hours' use will have you quite familiar with them.

Looking at tuning first, you have the choice of directly inputting frequencies via a keypad (having first selected the band you want), scanning the band via a pair of up or down pushbuttons, or manually tuning via a large knurled knob.

And speaking of that knob, it's very reminiscent of those found on receivers of yore – big enough to make fine tuning easy – about the only thing it doesn't do is zoom from one end of the dial to the other when given a good spin, like some of those older, heavier tuning knobs used to do!

Like most scanning receivers we've experienced, it only temporarily stops when it finds a station so if you want to listen in to that one, you have to hit the scanning button once again. (They call it pre-listening). Note that there is no auto-scanning available on SW/SSB [understandable] nor on the AIR band [why not?].

Alongside the direct-entry keypad buttons are further buttons controlling wide/normal bandwidth, AM/USB/LSB, FM mono/stereo and single-press buttons for FM, MW/LW, SW, and air bands.

A large (80 x 35mm) LCD screen displays a vast amount of information: the tuned frequency and the band in use, of course but also detail such as the timer and alarm settings, various modes such as the shortwave (metre) band in use, USB or LSB, FM stereo or mono, narrow or wide bandwidth, battery strength, fast or slow tuning steps and also information about the memories in use. There's also a bargraph on the left side which shows signal strength.

Other controls are the volume, bass and treble knobs on the left (though the bass control doesn't seem to affect bass so much as volume), while on the right are RF gain, squelch and SSB BFO (beat frequency oscillator) knobs.

There's also a nice big red power button, sleep, antenna attenuation, fast/slow step and reset buttons plus time/timer/alarm set buttons and one which controls both the dial light and also the snooze function.

Finally, an analog signal strength meter displays both "S" units and a 1-5 relative scale. However, we found this a little too small and too deeply recessed to be of much use. That might change with familiarity, of course.

Sensitivity and selectivity

Apart from the frequency ranges covered, two of the most important specifications for a serious listener are the receiver's sensitivity – its ability to receive extremely weak stations; and its selectivity – the ability to separate, or resolve, two stations close together on the band, particularly if one is strong and one is weak.

The Tecsun S-2000 quotes sensitivity and selectivity figures which are not too bad at all – more than adequate for the vast majority of applications and very good for what amounts to a relatively low cost receiver. (Yes, you can do marginally better, but be prepared to pay a *lot* more!).

In use

The first thing you notice about the Tecsun S-2000 – apart from the styling – is its great audio quality, especially on the AM & FM broadcast bands. This is thanks to its large (~100mm) inbuilt speaker. There is a tiny amount of "digital whine" off-station or in very weak stations but I did not find it objectionable.

But of course listening to the broadcast bands is not the main reason for buying a receiver of this type.

The second point to note is the very low noise floor – it seems to do a great job of lifting DX or weak stations out of the noise. That's important.

Using the inbuilt antennas for shortwave, air band etc is always going to be a compromise – there's nothing like hooking up an external antenna. Hooking in a long-wire antenna will reveal stations you didn't know existed. But even if you don't have the room for a large outside antenna, Tecsun Radios Australia have a couple of indoor or limited-area options (eg, loop antennas) available to assist you there.

If you cannot plug in an external antenna and you're plagued by interference (either another station or electronic noise), you may find the rotating antenna (on top of the set) is able to null out the noise and give you the station you want.

One thing I found (to my delight) was the stability of the radio. SSB, in particular, can often suffer from drift but once tuned in, I didn't have to nudge the dial once.

If you want to listen to a particular station at a particular time, the Tecsun has all the alarm functions you could want. And with audio output, it makes for convenient recording if you wish.

However . . .

I mentioned its stability a moment ago. While that's true, it does have one curious "quirk". Normally, when you start to tune off an AM station, sibilants (the hissing sound on words with an "S" sound) become more and more pronounced until you start losing the signal completely.

On most receivers, this starts happening just a few kilohertz off the station frequency.

The quirk which I noticed with the Tecsun S-2000 is that this doesn't tend to happen – in fact, if you tune a few kilohertz off the station frequency, the recovered audio actually sounds better than right on frequency!

For example, I tuned to Sydney's 2GB on 873kHz (AM) via the direct entry (keyboard) method. Fair enough, the audio was more than acceptable. But nudging the tuning dial a little in either direction (eg, 869 or 878kHz) and the audio was even better! No, I have no explanation on either how or why this happens (perhaps it has something to do with the inbuilt filters) . . . but I went online and discovered other reviewers have found exactly the same thing.

It's not a major criticism of the Tecsun S-2000 but, like the bass control which doesn't seem to affect bass, it's a criticism nevertheless.

The BFO (beat frequency oscillator, used to resolve SSB signals) is not particularly linear in operation; in fact it seems to have much more effect in a clockwise direction (from zero) than in an anti-clockwise direction.

I'm not sure that this is not a design "feature" but it is, well, different!

Typical of many aircraft-band radios, you really need to be reasonably close to the aircraft or airport, otherwise you're likely to be disappointed. I didn't have a tuned air-band antenna to check it out on but I'm sure it would improve things considerably over the built-in telescopic whip antenna.

Conclusion

It's a good performer, especially for the money. It's quite easy to use and should give you countless hours enjoying listening to stations from around the world. Having the extra bands is a real bonus – not everyone wants to sit there for hours with an ear up against the speaker, straining to hear that almost-there shortwave or amateur station.

You need to remember that this is NOT a communications receiver in the true sense of the word (and as discussed earlier). It's a very nice, low cost, LW/AM/shortwave receiver with FM radio and air bands – and lots of "niceties" – thrown in! To do any better at all (and even that's arguable), you're going to have to spend a *lot* more money!

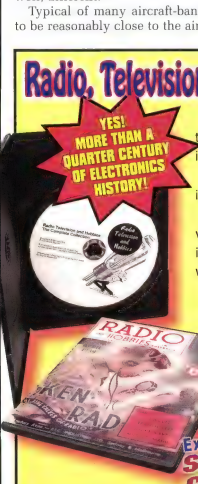
For the vast majority of users it will prove not just good but great – in fact, many comments I've seen on line suggest it's an even better performer than many of those sets costing significantly more.

While it looks the part, it doesn't have the weight of communications receivers simply because it has a switch-mode supply. This doesn't appear to introduce much in the way of digital interference to the receiver, so it's well shielded.

The Tecsun S-2000 retails for $425.00 (inc GST but plus p&p) and is available from Tecsun Radios Australia, Unit 2, 49 Powells Rd, Brookvale NSW 2100; tel (02) 9939 4377.

You can check it out, along with the range of accessories available, on their website: www.tecsunradios.com.au SC

Radio, Television & Hobbies: the COMPLETE archive on DVD



This remarkable collection of PDFs ***covers every issue*** of R & H, as it was known from the beginning (April 1939 – price sixpence!) right through to the final edition of R, TV & H in March 1965, before it disappeared forever with the change of name to EA.

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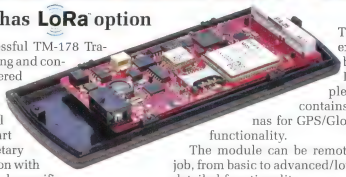


KCS has upgraded its successful TM-178 TraceME module, targeted for tracing and controlling vehicles and other powered equipment.

The TM-178/R9H7 module has been upgraded with optional LoRa, Wi-Fi, Bluetooth Smart (BLE), ANT/ANT+ and proprietary RF, which enables easy integration with existing wireless networks and specific custom mobile apps on smartphones and tablets.

LoRa technology offers a communication range up to 60km line of sight. The module offers an advanced indoor and outdoor location based positioning solution, which covers a variety of IoT applications and enables stolen object/vehicle recovery.

The TM-178 is equipped with external power and battery backup connection, basic I/O-connectivity and multiple on-board sensors. The unit contains multiple integrated antennas for GPS/Glonass, GSM (2G/3G) and RF functionality.

The module can be remotely programmed to fit any job, from basic to advanced/low-level application-specific detailed functionality.

With a compact size of 91 x 40mm, weighing 30 grams and a battery life of more than 10 years, the module offers endless OEM integration possibilities.

The module can be ordered in an optional robust IP67 housing.

Please visit www.trace.me for more information.

PCBCart Prototyping Service now supports maker and hardware startups

With the increasing popularity of the Maker movement, PCBCart has received more PCB prototyping and assembly enquiries than ever before. To show their support for Maker and hardware startups, they recently reduced their PCB prototyping and assembly services prices, with prototype boards starting from $0.19!

They also charge an extremely low assembly labor cost if you want your prototype assembled. If it's your first order, their New Customer Offer can save you 15% (up to $200) off your first PCB order.

Even with the lowered price, the same strict standards during proto board manufacturing and assembly is maintained. Your PCB file review and DFM check are the same as PCB full production orders.

Do you have a prototype project right now? Use PCBCart's online PCB Price Calculator at www.pcbcart.com/quote/prototype-pcb to get an instant quotation. A custom quotation will be provided within 1-2 working days.

Jaycar reaches 100 Store milestone

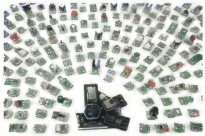
Jaycar Electronics has just announced the opening of their 100th store in Brighton, Victoria.

The milestone is just one of many for the successful Australian-owned company, which opened their first store in 1981 in Sussex St, Sydney.

Jaycar's newest store is located at the corner of Nepean Hwy & Hawthorn Rd, Brighton East, and is open seven days. The open-plan store has thousands of techo gadgets, electronics, car and home audio products, power products, automotive accessories as well as security, computer and outdoor products.

Many more stores are planned, as well as expanding their network of authorised stockists across Australia, New Zealand and Pacific Islands.

Byte-sized click boards give makers food for thought



In bygone days, software developers used to code with punchcards. A lot of menial work had to be done to write a program. High-level programming languages changed that. Software engineers using modern tools don't have to do the same thing twice. But what about hardware? Is there a way to avoid the repetitive work: wire jumpers on breadboards, soldering?

There are several add-on board producers on the market that try to simplify hardware prototyping.

MikroElektronika has been catching a lot of attention with their "click board" eco-system. A range of more than 200 byte-sized add-on boards, all with the same standardised connector, will give food for thought to any hardware developer.

On the surface, a click board is one of hundreds of add-on boards compatible with mikroBUS – a standard that specifies its size, shape and 16-pin connector. In essence, what hardware developers really get with a click board is a team of engineers working under them.

A developer picks the chip or module their project requires. MikroElektronika's engineers have done the legwork: figured out the configuration of resistors and capacitors, wrote sample code and libraries, even soldered the pins.

Most of today's major development platforms work with click boards. With adaptors, click boards can be matched to Arduino and Raspberry Pi. Microchip endorsed the standard on their new development boards. Hummingboard-gate is the first single board computer natively compatible with click boards.

Find a click for your project, plug it into a mikroBUS socket and start turning ideas into prototypes with new-found freedom.

Click and Microcontroller boards are available from Glyn: www.glynstore.com/mikroelektronika/

ElectronEX returns to Sydney in September

Electronex, Australia's only dedicated trade event for the electronics industry, returns to Sydney on 14–15 September at Australian Technology Park. With around 100 exhibitors, a technical conference and free seminars featuring leading international and local industry experts, this is an event not to be missed.

This year's expo continues to reflect the move towards niche and specialised manufacturing applications in the electronics sector and will also cater for the increasing demand from visitors for contract manufacturing solutions. There is expected to be a record number of exhibitors participating as the industry is seeing an upturn in demand from local manufacturers and specialist applications that are recognising the expertise and quality that is available from Australian-based suppliers.

The event targets design professionals; electronic and electrical engineers and technicians; along with OEM, scientific, IT and communications professionals and service technicians. Electronex was launched in 2010 to provide professionals across an array of industry sectors with the opportunity to learn about the latest technology developments for systems integration and production electronics. The last Sydney show in 2014 attracted over 1000 trade and industry visitors.

Visitors can pre-register to attend the expo for free at www.electronex.com.au.

The SMCBA Electronics Design & Manufacture Conference (founded in 1988 and held in conjunction with Electronex) will bring together local and international speakers to share information critical to the successful design and development of leading-edge electronic products and systems engineering solutions. A series of free seminars with overviews on key industry topics will also be held on the show floor throughout the two day event.

The conference will include the following presentations (the complete conference and seminar program can be found on the show website).

Dr S Manian Ramkumar, Director – Center for Electronics Manufacturing and Assembly, Rochester Institute of Technology, will deliver three presentations: Defect Analysis and Process Troubleshooting; Characterising and Minimising Voids in QFN Device Assembly Using Lead Free Solder Alloys; and Root Cause Analysis for Reliability Issues in Electronics Packaging.

Dale Lee, Plexus Corporation, Staff DFX Process Engineer, will deliver two presentations: DFX Design for Excellence: DFM, DFA, DFT and More; and Flex PCB Design and Assembly.

Simon Blyth, Director of Engineering, LX Group, will deliver a presentation on the Internet of Things.

Dr Hamish Laird, ELMG Digital Power, will deliver a presentation on High Performance Digital Control.

Mark Steiner, Managing Director, Hetech, will deliver a presentation entitled To Design or not to Design a Commercial View to Product Development.

Details: When: 14–15 September 2016
Where: Australian Technology Park, Sydney
Website: www.electronex.com.au

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Vintage Radio

By Ian Batty

Astor Aladdin FG Dual-Band Receiver

Good performance from four valves

Using just four valves, Astor's Aladdin FG is an interesting battery-operated set with a vibrator power supply and a reflexed IF amplifier/first audio stage. Restoring this particular unit to full working order proved to be straightforward.

THE ASTOR Aladdin FG really is an interesting set, partly because of its age and partly because of its advanced design (for the time). I bought this particular radio at a Historical Radio Society of Australia (HRSA) auction some years ago, mainly for its Art Deco styling. When I subsequently discovered that it was a 6V DC set with a vibrator supply, I left it on my display shelf for some years.

Just recently, I decided that it was time to dust the old Astor off and rediscover this classic piece of design from 1937. That's almost 80 years ago!

This is a 4-valve superhet set with two IF stages, the last one being reflexed. It's a dual-wave (broadcast and shortwave) design and I was interested in finding out if Astor had overcome a fault inherent in many early directly-heated designs, namely unreliable local oscillator (LO) operation.

The Art Deco styling aside, one of the first things you notice about the Aladdin FG is that it's quite a heavy set (10kg). This is partly due to the transformer used in the vibrator power supply and its associated shielding and filtering circuits. The steel chassis also contributes to the set's weight.

Visually, it's one of those sets that really catches the eye, with its large dial and the three bars across the speaker grille. The 2-part dial features switched dial-lights which illuminate the selected band (broadcast uppermost, shortwave below), as well as two magnifying windows to allow for more accurate tuning.

The leftmost control turns the set on and offers three tone control positions: "normal", "soft" and "softer". The volume control sits in the middle, just to the left of the dial, while the band switch is immediately below it. The remaining control at far right is the tuning knob.

As shown in the photos, the set is built on a conventional "bathtub" chassis, with a separate insert chassis for the aerial/oscillator coil pack. The valves used are either 6-pin (V1-V3) or 5-pin based (V4).

Circuit details

Fig.1 shows the circuit details of the Astor Aladdin FG. As mentioned earlier, it's a 4-valve 6V DC set with a vibrator power supply. In fact, most 6/12V valve sets used vibrator power supplies, with valve-based car radios probably the most familiar of these. A few exceptions used motor-generator (genemotor) supplies.

In operation, a vibrator uses a vibrating reed to switch battery current through the push-pull primary windings of a step-up transformer. By operating at 100Hz, vibrator supplies can use smaller transformers and filter components than 50Hz mains supplies.

The vibrator's major drawbacks are: (1) a limited life-span due to contact corrosion and (2) a high degree of radio-frequency interference (RFI). This RFI

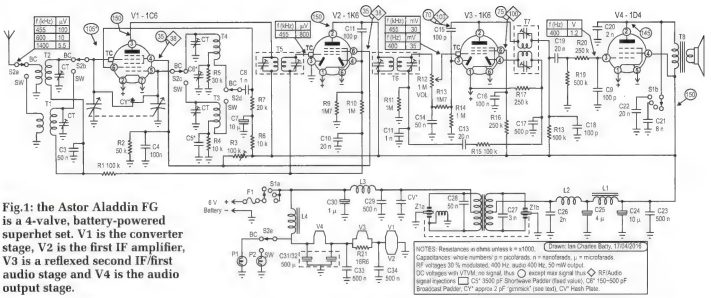


Fig.1: the Astor Aladdin FG is a 4-valve, battery-powered superhet set. V1 is the converter stage, V2 is the first IF amplifier, V3 is a reflexed second IF/first audio stage and V4 is the audio output stage.

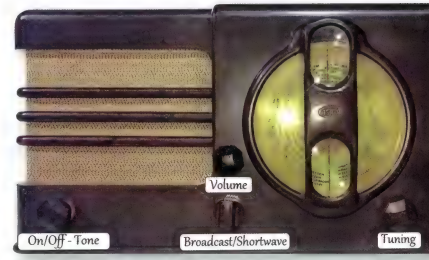
is mainly generated when the current through the transformer is interrupted each time the contacts open. Since the transformer is heavily loaded by the rectifier connected to its secondary, we might expect that back-EMF and sparking would be kept down but there's still a substantial amount of RFI in even the best designs.

This means that careful filtering and shielding are a vital part of any vibrator supply design. The Aladdin FG's circuit reflects this, with heavy filtering on the input side (L3, C30, C29 & CV), the secondary (C26, L2 & C23), and even in the filament circuit (C31/32, C33 & C34). CV, the "hash plate", is a common feature of vibrator supplies. It's usually a simple metal plate riveted to the chassis but isolated by a sheet of mica or fibre insulation.

There's also C28 & C27. You may not find a capacitor (C28) on the primary in all designs but you will see the equivalent of C27. This is the buffer capacitor and it's there to damp out high-voltage transients in the primary circuit due to contact openings.

This capacitor is typically a high-voltage, high-reliability type (2kV in this 160V supply), as a short-circuit failure will stop the power supply dead. It could also damage the vibrator or transformer, as the vibrator would be attempting to switch the supply voltage to ground with virtually no transformer primary inductance to limit the current flow.

Conversely, an open-circuit capacitor will result in excessive sparking at the vibrator contacts, leading in turn to greatly-shortened vibrator life.



This view shows the control layout on the front panel. Note the two magnifying windows that form part of the dial-scale tuning indicator.

Many vibrator sets use a valve rectifier such as a 6X5, 6V4 or 6X4. While these work just fine, the alternative is to economise on valve count and use the vibrator itself as a rectifier. The FG circuit uses just such a design – Z1 is a synchronous vibrator, with Z1a on the low-voltage DC-AC side and Z1b on the high-voltage AC-DC side.

Note that simpler, non-synchronous vibrator supplies can work just fine with reverse battery polarity but the FG's synchronous design would give a negative output with battery reversal.

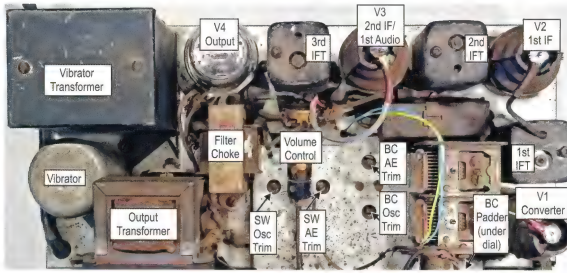
You'll find an excellent description of vibrator supplies in the references listed in an accompanying panel. And as always, there's the Radiotron Designer's Handbook (RDH) which is also listed (see chapter 32).

Astor Aladdin FG controls

As stated, early dual-wave sets suffered from unreliable local oscillator operation on the shortwave band. In fact, the very first 2V converter valve, the 1A6, was unreliable even on broadcast band frequencies.

The 1C6 (octal version = 1C7) converter used in the Aladdin FG was a much better performer. This improved performance was achieved by doubling the 1A6's filament current to 120mA and is a reminder that filament emission is as important as physical design in valve performance.

The 1C6 (a pentagrid) uses grid 1



This view shows the layout on the top of the chassis. The set was in quite good condition considering that it's now almost 80 years old.

as the oscillator grid and grid 2 as the oscillator anode. Grids 3 & 5 form screens, while grid 4 is the signal grid.

Ideally, the LO (local oscillator) only interacts with the incoming signal inside the anode cylinder. Any extraneous interaction has little effect on broadcast frequencies, as the LO frequency and tuned signal frequency are some 455kHz apart.

On shortwave, it's a different story. At this set's top end (around 18MHz), the LO is less than 3% away from the tuned frequency, so any external interaction will affect the valve's input impedance and disturb the aerial circuit tuning. Unfortunately, good physical design cannot defeat the main source of such interaction – a space charge effect occurring inside the valve itself.

The solution, as seen in many multiband sets, is to apply a neutralising signal via a 2-5pF capacitor. In the Aladdin FG, it consists of a short length of wire which runs from the oscillator section of the gang and is wound around the aerial circuit converter's top cap lead (CY). It's commonly called a "gimmick" capacitor.

The local oscillator uses "padder" feedback. It's a form of Hartley oscillator, with the anode supplying a signal via bandswitch S2d to either T4 (BC) or T3 (SW). The signal is then fed back to the oscillator grid via bandswitch S2c. Each band has its own padder capacitor, this being either C6 or C5. C6 is used for the broadcast band and is adjustable, while C5 is switched in for shortwave and is fixed.

As well as reducing the LO's frequency span (to ensure tracking), the selected padder returns its coil tapping almost to ground, the actual impedance to ground being the padder's capacitive reactance. This tapping (added to inductive coupling within the coil) provides sufficient feedback to sustain oscillation and provides the phase reversal needed for the oscillator to work.

Note that each padder is shunted by a grid resistor (either R5 or R4), with R4 (shortwave) being just 10kΩ to help maintain oscillator activity over its 6-18MHz range. Note also that the adjustable broadcast-band padder (C6) is accessed via a hole in the front of the chassis, just below the dial (not where you'd usually look)!

You'll find a thorough description of converters in chapter 26 of the Radiotron Designers Handbook (RDH). Alternatively, for a less mathematical but more extensive descriptive article, check out "Converters & Fault-finding" in the HRSA's *Radio Waves* for April 2012.

Getting back to the circuit, the signal from the converter drives double-tuned IF transformer T5. The resulting IF signal is then fed to the first IF amplifier stage (V2).

At first glance, I could see only one adjustment per IF can, consisting of a slotted, threaded shaft. However, closer inspection of each can showed that I'd mistaken what was a second adjustment for a lock-nut. It turned out that the two adjustments are coaxial; the nut is used for one trimmer adjustment, the threaded shaft for the other.

IF arrangement

IF amplifier stage V2, a 1K6, is a duo-diode pentode. It uses one of its diodes (fed via C11) to provide AGC (automatic gain control) for both itself and the converter (V1). The control voltage is fed back via R10 and R1 and is filtered by capacitors C10 and C3.

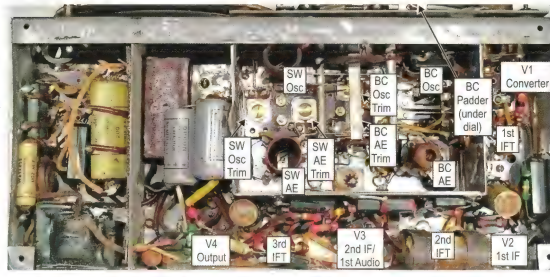
This is rather an odd arrangement since the AGC voltage is usually derived from the final IF amplifier stage in the chain. It turns out, though, that the second IF amplifier stage based on V3 has its own AGC.

The volume control varies both the IF signal level and the audio signal level fed to V3. Basically, this is a 4-valve set with five stages. V3 is reflexed; it amplifies both the IF signal and the audio signal, so it acts as both a second IF amplifier stage and as a first audio amplifier stage.

It's an economical and elegant arrangement that performs almost as well as a conventional 5-valve set. Its main drawback is that, unless precautions are taken, it can suffer on strong signals if the reflexed valve (V3 in this case) rectifies the IF signal at its grid rather than using its internal demodulator diode.

Chapter 28 of the Radiotron Designer's Handbook describes the basic principles and this set's design also gives us the clues as to how it all works. First of all, applying AGC to V1 & V2 helps to ensure that a fairly constant signal is fed to V3's grid. Second, placing the volume control in the IF path means that the IF signal level is reduced on strong signals, along with the audio signal level. And third, applying local AGC to V3 also helps to prevent overloading on strong signals.

In greater detail, V3 feeds its demodulator diode via IF transformer T7. The demodulated audio is then filtered by C17 and fed to V3's grid via R15, C13, IF transformer T6 and volume control



The parts under the chassis are tightly packed but still accessible. Note the separate chassis insert which houses the band-switch and its associated antenna and oscillator coils.

R12. V3's AGC diode is fed directly from the valve's anode via C15, with the resulting control voltage fed via R13 to the bottom of the volume pot. This provides local AGC for the stage.

Note that the demodulator diode's DC return, via R17 to V3's filament, places zero bias on the diode. As a result, it will respond to all signals as it's intended to do. By contrast, the AGC diode's DC return is to ground via R14. Since V3's filament is some 2V above ground, this applies a small "delay" voltage to V3's AGC circuit.

V3's anode current contains two signals: the 455kHz IF signal and the demodulated audio signal. The IF signal is recovered by IF transformer T7, while the audio signal is fed to output valve V4 via C19. Capacitors C18 & C9 eliminate any residual IF signal from the recovered audio.

V4 is a straightforward class-A stage. It gets around 4V of bias because it's at the top of the filament chain, so its grid resistor (R19) simply returns to ground. The Power/Tone switch (S1) switches in treble cut using either C21 or C22, while C20 is permanently in circuit to damp output transformer T8's natural high-frequency resonance.

Getting it going

Despite its age, the Aladdin FG's Bakelite cabinet was in fine physical condition as it came to me, with only some yellowing of the dial covers detracting from its appearance. There was some rust on the rear spreader bar and the usual dust on the valves, chassis and IF cans but this was to be expected after nearly 80 years!

When I switched it on, the set was dead. I should at least have heard the vibrator buzz but it just sat there, drawing about 250mA from a 6V supply. That was consistent with all the valves drawing filament current, so I pulled the vibrator from its socket and removed its outer case.

This revealed that the foam rubber insulation/sound deadening lining inside had badly deteriorated and some had collected in the bottom of the can as a kind of "goop". Worse still, this "goop" had coated the reed and the contacts, thus preventing the vibrator from operating.

Brushing the "goop" with turpentine and scraping it away gave some improvement but it wasn't enough. In the end, I undid the screws holding the contact assembly and the reed, removed the reed and cleaned both it and the frame it sat in. I then cleaned the contacts and after reassembly, the vibrator unit worked just fine.

There were still problems with the radio itself though, with weak reception, distorted sound and no AGC action. Subsequent valve tests showed that valves V2 and V4 weak, so they were replaced.

Further Reading: Vibrator Power Supplies

(1) www.radioremembered.org/vpwrsup.htm
(2) Radiotron Designer's Handbook; eg, http://frank.yueksel.org/other/RCA/Radiotron_Designers-Handbook_Fourth-Edition/
(3) A Practical Guide To Vibrator Power Supplies (in Vintage Radio), Silicon Chip, December 2015.

I then found that the audio on V4's grid was being clipped on positive peaks. The culprit turned out to be coupling capacitor C19; it was leaky and putting a positive voltage on V4's grid.

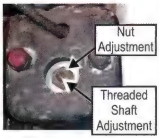
After replacing this capacitor, I found that I could inject an RF signal and see V3's screen voltage rise as its local AGC cut back its control grid bias. Checking the screen voltage in AGC-controlled stages is a handy diagnostic procedure, especially on battery valves where cathode resistors (and cathode voltages) are absent.

What about V1 & V2, the converter and first IF amplifier stages? As shown in Fig.1, their commoned screen circuits (pins 4 & 6 respectively) have an adjustable voltage divider consisting of variable resistor R3 (the "sensitivity control"). However, even with such a voltage divider to stabilise screen voltages, I'd still expect to see some local AGC action in response to signals but there was nothing.

Measuring along the circuit, I found that the connection between the bottom of R10 and the first IF transformer was shorted to ground. Capacitor C10 was the first suspect but disconnecting it made no difference. Eventually, after a bit of mucking about, I discovered that the fault lay in the first IF transformer (T5).

I quickly disassembled T5 and I found that the one of the moving plates on one of the compression trimmers had shorted. Loosening the trimmer's retaining screws allowed me to slide the offending plate into its correct position and remove this short circuit.

The question was, had this fault been there from the day the set was made? It's quite possible, as it's obvi-



The set's IF coils each have two internal adjustments, one made via a threaded shaft and the other via a nut.

ous that the coil can had not previously been opened.

Fig.1 shows the oscillator anode's voltage to be at 105V. Measuring at this point will often stop the oscillator dead and that's what all my meters did. So, in order to measure this voltage, I used a 10MΩ DVM with a 1MΩ resistor connected in series. The 105V value was then calculated from the measurement after allowing for a 10% (approximate) voltage drop across the series resistor.

Plumber's tape

The Aladdin FG uses Bakelite knobs, three of which have brass inserts to minimise the chances of the grub screws stripping their threads. This is important because both the volume and tuning shafts lack "flats", which means that the grub screws need to be as tight as possible so that the knobs don't slip.

Unfortunately, the only knob that didn't have a brass insert had a stripped thread. I could have re-tapped it and used a larger grub screw but I opted instead for an old friend – Teflon plumber's tape. A short piece, folded over four times and inserted in the hole did the job and allowed the grub screw to be tightened up quite nicely.

Teflon tape also makes an excellent "binder" for ferrite slugs, unlike wax or lacquers which solidify and jam slugs in position.

The sensitivity control

As noted above, variable resistor R3 sets the screen voltages for V1 and V2. The original circuit shows only about 35V, just over half the manufacturer's ratings of some 67.5V for these valves and half V3's screen voltage of 70V.

A gain reduction that's achieved by using reduced screen voltages is common in sets with two IF stages. That's because feedback within the chassis would readily lead to the entire IF circuit "taking off" (or oscillating) if the rated voltages were used.

As an experiment, I tried increasing the screen voltages on V1 & V2 to 70V and this particular set "behaved". This resulted in a sensitivity of about 4μV for a 50mW output, which is on a par with the AWA set referred to below.

Conventional contemporaries

Some three years after the Aladdin FG, AWA described a 5-valve set using the new 1.4V octal line-up in the company's *Radiotronics* magazine No. 104, May 1940. Using an RF stage and a single IF stage without reflexing, this set managed a sensitivity of 3μV for 50mW output but with poorer noise figures than the Aladdin FG's.

Unlike the Aladdin FG, the RF and IF amplifiers in AWA's set operated with full screen voltage. However, when operating the two sets side by side, I doubt that anyone would pick any difference in sensitivity.

How good is it?

So just how good is it? Well, considering it's a 4-valve battery set, it's pretty good. With better than 10μV sensitivity on the broadcast band, an impressive 0.5W output, a power consumption of just 7W, a shortwave band and an elegant cabinet, what's not to like?

If you couldn't afford a large console radio running off battery power at the time, the Aladdin FG would have been an excellent choice. And it would have sat nicely on the mantelpiece.

The measured results back up the subjective impressions. At 600kHz, its sensitivity is 10μV for the standard 50mW output. This figure improves to just 5.5μV at 1400kHz. The corresponding noise figures at 600kHz and 1400kHz are 18dB and 15dB respectively, while a 20dB signal-to-noise ratio would require signal levels of about 12μV and 8μV respectively.

On shortwave, it needed around 16μV at 8MHz but this reduced to just 4μV at 17MHz. It was, however, quite noisy at the high end, with a signal-to-noise ratio of around 6dB. The sensitivity at 8MHz figure was improved to around 12μV by placing a "magic wand" in the aerial coil, indicating some misalignment and highlighting the limitations of not providing any low-end shortwave adjustment.

The IF bandwidth was only about ±1.4kHz at -3dB and ±12.5kHz at -60dB, so three double-tuned IFs can really give high selectivity. That would be an advantage in country areas when trying to pick up distant stations. Unfortunately, the AGC didn't work all that well, with the output increasing by some 6dB in response to a signal increase of just 14dB.

The maximum audio output was also checked and this gave a figure of 500mW at around 11% distortion. At 50mW, the distortion was around 3%, while at 10mW it's around 7%. The frequency response was 240Hz to 3kHz at the -3dB points between the volume control and the speaker but only about 240Hz to 1 kHz between the aerial terminal and speaker, confirming the very narrow IF bandwidth.

Switching in the tone control cut the frequency response at the top end even further, to 600Hz or 500Hz depending on the setting.

Despite these modest figures, I'm pretty happy with the performance of my Aladdin FG and its distinctive looks make it a valuable addition to my vintage radio collection. SC

ASK SILICON CHIP

Got a technical problem? Can't understand a piece of jargon or some technical principle? Drop us a line and we'll answer your question. Send your email to silicon@siliconchip.com.au

Arduino MFM glitch problem

I am using an Arduino MFM (SILICON CHIP, April & May 2016) to measure the output of a null meter. The signal that I am measuring ranges from +100mV to zero to -100mV.

When the null meter approaches zero and/or goes negative, the MFM readings randomly go up from a few millivolts to ~2.5V. Is there a way to prevent the sudden change in what the MFM is seeing and recording around zero input signal levels? (L. A., via email).

● We have found the solution to that random 2.5V reading problem with the MFM's Arduino sketch. The reason for the occasional full-scale readings was that when the input voltage is very close to zero, noise and/or hum can send it briefly negative and the LTC2400 ADC chip's output swings negative accordingly: to FFFFFF (hex), then FFFFFE and so on.

We didn't take this possibility into account previously and as a result the MFM sketch regarded FFFFFF as corresponding to 2.500V and so on. We also discovered that Linear Tech had provided status bits in the 'header' sent before the actual digital data output, which can be used to learn whether the input voltage was positive or negative. Our sketch originally masked off these header bits because we didn't think we'd need them.

The firmware sketch has now been modified to extract the status bits and analyse them, so that negative inputs produce the appropriate output. You can download the modified software from our website.

Capacitor ratings for Ultra-LD amplifier

I am getting around to building the Majestic speakers (June & September 2014) with the Celestion 28/FTR15-4080FD 15-inch driver (rated at 1000W RMS). To drive these, I want to build the Ultra-LD Mk.3 amplifier (March-May 2012).

Given that I could be operating the amplifier at or near full power for extended periods to drive these speakers, should I replace the six original 4700µF power supply filter capacitors with 6800µF capacitors (eg, RS Components part #739-5386)? Would this help the power supply cope with a prolonged high load situation?

Besides the capacitance, the only other difference I can see from the originally specified capacitors is that the original ones have a ripple current rating of 3560mA while the proposed RS-sourced capacitors have a ripple current rating of 2800mA. Another option could be to add another two of the original capacitors and/or use a higher-rated toroidal mains transformer.

Your expert thoughts would be greatly appreciated. I want to add a big thank you for the great magazine; my wife tells me I am like a kid in a lolly shop when it arrives in the post. (J. C., Armadale, WA.)

● Substituting 6800µF capacitors with a lower ripple current rating than the 4700µF units we originally specified would be a backward step. If you are going to add filter capacitance, you want more ripple current capacity; not less.

However, even if you doubled the power supply filter capacitance and overall ripple current rating it would make little, if any, difference to the

Valve Preamplifier Gain Questioned

I note that on page 76 of the February 2016 issue, the gain of the Hifi Valve Stereo Preamplifier is listed as 12dB. This seems an unusually low and impractical value. The valve preamp from S5 Electronics has a gain from 10dB to 30dB and the ART DJ SS phono preamp (widely used here) is 45dB. My Emotiva XSP-1 has a preamp section that also provides 40dB of gain.

The advice to change resistors to raise the gain is well and good but the quoted S/N ratio of 105dB is for a near unusable gain (I think). What is the S/N ratio for the maximum quoted gain of 20dB?

My Ortofon 2M Blue MM cartridge has an output of 5.5mV. Running your preamp at full power with the maximum resistor value will supply the power amplifier with 55mV; still about half what's required for full output of most amplifiers (I think). (W. B., Croydon, SA.)

● Typically, the signal-to-noise ratio will be inversely proportional to the gain so if the gain is increased from +12dB to +20dB, the S/N ratio will be reduced from 105dB to 97dB.

This preamplifier will not work with any magnetic cartridge because it does not have the components to provide RIAA/IEC equalisation which involves almost 18dB of boost at 50Hz and 20dB of cut at 20kHz.

It is our opinion that valve preamplifiers providing sufficient gain and accurate RIAA/IEC equalisation are unlikely to provide a signal-to-noise ratio of better than -65dB with respect to an input signal of 10mV at 1kHz. Note that most power amplifiers require an input signal of between 500mV and 1V RMS to be driven to full power.

If you want a high-performance magnetic cartridge preamplifier, a valve circuit won't do it – a solid-state preamp, like the ART DJ, is the only viable approach. Our most recent high-performance magnetic cartridge preamplifier was published in the August 2006 issue. You can see a preview at: www.siliconchip.com.au/Issue/2006/August/Build+A+Magnetic+Cartridge+Preamplifier

Queries On Anti-Fouling For Boats

I am building the Ultrasonic Anti-Fouling Unit For Boats from the September & November 2010 issues of SILICON CHIP and I have two queries about it. First, it has tended to blow the fuse at start-up on several occasions and I was advised by the staff at Jaycar to fit a 5A slow-blow fuse. Is that OK?

Second, my boat only has one battery and I am concerned about the low-voltage cut-out setting of 11.5V. If the unit discharges my battery down to that point, there is a good chance that it might be so discharged that it will not start the motor. Can I increase the cut-out setting to 12V and how do I do that?

By the way, I do have a solar panel and charger on the boat to keep the battery topped up. (G. E., via email).

● There are two ways to increase the cut-out voltage to 12V. First, simply set trimpot VR1 to provide a voltage of 5.2V at TP1. Alternatively, you could change the resistive divider whereby the microcontroller senses the battery voltage. To do this, connect a 150kΩ resistor across the 10kΩ resistor from pin 5 of IC2 to ground. This changes the resistance of the lower voltage divider from 10kΩ to 9.375kΩ. The 10kΩ resistor to be shunted is located to the right of the two 22pF capacitors and just below the 10µF capacitor.

When the battery voltage is 12V, the divider provides 3.83V to pin 5 and this is the switch-off threshold. However, the microcontroller's program does incorporate hysteresis whereby the battery voltage will need to rise to 12.53V (that's 4V at pin 5) for the anti-fouling circuit to start up again.

Since your boat has a solar panel and charger, we would be inclined to leave the cut-out voltage as originally set, since your battery is only likely to be discharged to 11.5V during a long period where there is little output from the solar panel. This might be a week or more so if you live in sunny climes, it is not likely to be a problem.

On the other hand, if your boat did not have a solar power charger and was on a swing mooring whereby you needed to start the motor every fortnight or so to ensure that the battery was reasonably charged, increasing the cut-out voltage is possibly a good strategy.

Over the years since this project was described we have had times where there has been a spate of readers complaining about the initial fuse blowing. We cannot identify the particular reason for this. The initial surge current is largely due to the low ESR of the specified 2200µF 25V capacitor. The solution suggested by Jaycar is valid: fit a 5A slow-blow fuse.

supply regulation because ultimately that is mainly determined by the losses in the power transformer and rectifier diodes.

What's more, since the amplifier is going to be driving the Majestics which are far more efficient than most other loudspeakers, then it should never be driven into clipping, unless of course, you are driving them to insane levels. In that case, clipping in the amplifier will be largely academic.

24V version of Solar MPPT Charger wanted

I read with interest your great article on the 120W, 12V MPPT Solar Charge Controller in the February 2016 edition. What would it take to upgrade this charge controller to run off larger and higher voltage panels (eg, 37V)?

The reason for asking is that house PV panels can often be obtained very cheaply (<$0.50/Wp) and are ideally suited to camper trailer or RV applications. However, they typically operate at 30V (37V open circuit). If the design is not readily upgradable, would you consider a follow-up design for higher voltage panels? (R. B., Gilston, Qld.)

● The panels you refer to, with a 30V peak operating voltage and 37V open-circuit voltage, are generally referred to as 24V (nominal) panels since they are designed to charge 24V batteries, which typically have a fully-charged voltage of around 28.8V. Thus the 24V version of the MPPT Solar Charger in the February and March 2016 issues is suitable.

It is designed to charge a 24V lead-acid battery and while doing this the PV panel would be typically producing power at its maximum power point (MPP) of around 36V. The MPPT charger is suitable for 24V panels up to 220W.

There are inevitably requests for a particular charger to be altered for higher power ratings. We do tend to upgrade these projects in time with extra power capabilities based on reader requests, depending on their economic validity.

Old flasher circuit could be updated

Is there a modern equivalent of a neon relaxation oscillator? Check out this ancient circuit: www.spoilsport-motors.com/Eico%20Electronic%20Mystifier%20kit%20from%206th%20grade.pdf

It has six neon relaxation oscillators which can be arranged to form interesting random light patterns. Do you reckon it could be updated using LEDs and somewhat smaller components? The copyright expired a while back, I think.

I wonder if zener diodes could be used to simulate the breakdown voltage of a neon lamp? (D. F., via email).

● The circuit requires neon discharge lamps in order to produce relaxation oscillators. Zener diodes do not have the necessary breakover/negative resistance characteristic and so they cannot provide the effect.

The only 2-terminal solid state device which has a similar breakover effect to a neon is a Diac and it would be feasible to produce a roughly equivalent relaxation oscillator circuit with sets of four components: a resistor, capacitor, Diac and a LED in series. But you would need a DC supply of 45V or thereabouts. In making such a circuit, you would have to ensure that the peak breakover current of the Diac did not blow the LED.

However, there is little point in building a Diac/LED relaxation oscillator, since flashing LEDs have long been available and they will run from a much lower voltage.

SIDAC-based CDI module

I am writing in regards to an item in Ask SILICON CHIP (April 2016) on how a CDI module works. I think that

the module the writer is talking about does not have a separate trigger coil as per the article in May 2008. The unit they are talking about is found in a lot of small 2-stroke motors (eg, Victa mowers) and only has one electrical connection from the coil.

These units appear to switch at a set voltage from the coil instead of using a separate trigger coil. As per a lot of other ignition modules, for the couple of components that are potted in a small case, it is very expensive to replace at $35 to $40. The manufacturer as usual has removed all markings from the components if you can get past the potting compound and there is only what looks like a couple of diodes and an SCR.

It may be worth having a look at this type of unit. (J. O., via email).

● Many very small engines, such as in chainsaws and lawn mowers, use a very simple ignition that is not a CDI but a standard Kettering style ignition. Earlier versions used ignition points but newer models use a SIDAC (Silicon Diode Alternating Current switch) instead of points.

This makes it maintenance-free (ie, no points wear) and gives automatic ignition timing advance with RPM. The SIDAC is similar to a DIAC but with a higher breakover voltage and higher current rating. The SIDAC has a relatively high impedance at voltages below its breakover point. Above that, the SIDAC has a low impedance until current flow drops below its holding current. In practice, it operates like a voltage-operated switch.

For ignition, the SIDAC is connected in the same way as the points. That is, between the junction of the high voltage generator coil and ignition coil primary and the chassis. The generator coil is also chassis-connected at the opposite end of its high voltage winding.

In operation, the ignition coil charges up via the magneto's high-voltage generator coil as the magnets rotate past this coil. The coil voltage builds until it reaches the SIDAC's breakover voltage and the SIDAC impedance then drops to near zero, effectively shorting the generator coil and connecting the ignition coil's primary to chassis. The resulting sudden change in ignition coil flux then generates the high-tension voltage in the coil's secondary to fire the spark plug.

It would be expected that the ignition timing would vary with engine RPM. That's because the high voltage generated by the flywheel coil would reach a higher value earlier (with respect to top dead centre [TDC]) at higher RPM. Ignition timing would therefore advance with RPM and by extension, would produce the required timing retard at idle.

The Victa designers would have selected the SIDAC breakover voltage to match the coil voltage generation characteristics. The overall timing would be set by the relative positions of the generator coil and rotating magnet during manufacture.

The SIDAC would probably not be used on its own; we cannot find a SIDAC that is rated for sufficient current to switch the ignition coil directly. Possibly, the SIDAC is used to fire an SCR that is rated at around 500V @ 10-15A, for reliability.

The SCR gate would be driven via the SIDAC from the coil generator supply (that is also connected to the SCR's anode). The SIDAC would also be connected in series with a suitable gate limiting resistor and a gate to cathode resistor. The SCR cathode is connected to chassis, assuming the generator develops a positive voltage. Alternatively, a TRIAC might have been used rather than an SCR.

Sourcing high-voltage axial capacitors

Are you able to tell me where I can purchase those wonderful high-voltage capacitors used in the Vintage Radio section, with the wires coming out of each end, as in the June 2016 issue? I have been trying for years to find where these are sold. (R. B., Heyfield, Vic.)

● We asked Kevin Poulter who replied: the HRSA (Historical Radio Society of Australia) has a range of these capacitors for sale at low rates to members. HRSA membership includes access to circuits, advice and a colour quarterly magazine, plus access to radios at low prices (restored or restorable) and parts; all for $35 per year – see www.hrsa.asn.au

I have two tips. First, select a capacitor with a significantly higher volts working rating than the HT rail. Second, some members empty out the contents of old capacitors and insert the new one, so the appearance is the same as original. You may want to consider doing the same.

LCD Hand Controller display is blank

I have purchased a number of Silicon Chip project kits over the years, primarily automotive and ignition-related. This includes the Programmable Ignition kit, the Coil Driver kit and the LCD Hand Controller. The first two function when powered up and produce a healthy spark using a Piranha optical switch in a V8 distibutor. I set this up on my workbench.

The issue I have is that the LCD Hand Controller kit fails to display

Driveway Monitor Detector Battery Problem

I built the Driveway Monitor (July & August 2015) from an Altronics kit (K4035). The detector unit doesn't power up reliably when the battery is inserted.

Sometimes the circuit will power up and I can measure 5.5V at TP5.5. At other times, it will not power up and I can only measure about 1V at TP5.5. When the detector powers up correctly, it works perfectly.

The battery is fully charged. Can you suggest a fix for this? (C. C., via email.)

● When inserting the cell into the holder, this can produce a series of connections and disconnections as the cell is moved and makes contact with the holder terminals. This can prevent the TL499a from starting up correctly. You can improve the start-up by inserting the cell first onto the spring contact of the holder and then pressing the cell into the holder, keeping the positive end away from the holder contact until the cell is fully inserted. Then release the cell so it makes contact with the positive terminal. Check for 5.5V at TP5.5.

Note that the circuit is not designed for the cell to be repeatedly removed and inserted but to be continuously powered by the cell. Best start-up reliability is when the cell is fully charged when inserted. Once running, the 5.5V should still be generated even if the cell discharges down to 1V.

Garage Parking Assistant Doesn't Work With Switchmode Supplies

I recently built the Garage Parking Assistant (described in the March 2016 issue). Everything seems to work fine, except that the range reading is all over the place. It will not stabilise.

I subsequently read in the July 2016 issue that someone else had the same problem (Ask SILICON CHIP, page 99) which was tracked down to hash on the 5V switchmode power supply used. I have now tried several different supplies, from USB chargers to a few different plugpacks but with the same results. That is, until I tried my lab supply, which gives me an absolutely stable reading.

However, as this unit is for my daughter's garage, I do not want to give her my lab supply as well. Do you have any suggestions on what my next move should be? (A.d.K., Ferntree Gully, Vic.)

● It now seems as though most switchmode supplies cause problems for the Garage Parking Assistant. The cure is to use an analog regulator such as our MiniReg from the December 2011 issue. The PCB could be housed in a small Jiffy box glued to the outside of any unregulated DC plugpack (transformer type) which delivers anywhere between 9 and 12V DC.

You can see a free 2-page preview of the article on our website at www.siliconchip.com.au/Issue/2011/December/MiniReg+1.3-22V+Adjustable+Regulator

any characters at all on the screen. The screen lights up but that is all. I have checked the circuit assembly but can find nothing obviously wrong with the placement of components or the soldering.

Can you please assist by pointing out why there is no character display? I powered up the kits only after the controller was pluged into both. I cannot find any diagnostic information for these kits anywhere. Your assistance would be greatly appreciated. (V. S., Melbourne, Vic).

● Make sure you have inserted and soldered in the wire link that is near the DB25 connector on the Hand Controller PCB. Also check the solder connections to the LCD, particularly pins 4 and 6.

Assuming those are OK, check for continuity between the pins on the DB25 connectors on each board with the cable plugged in, ie, pin 1 to pin 1, pin 2 to pin 2 etc. Sometimes the DB25 connectors have tarnished pins which can prevent a good connection.

Also, check the contrast trimpot on the Hand Controller's LCD. If it is wound too far anticlockwise, no display will be visible.

A powered LCD will show a series of black rectangles if it is not driven correctly, rather than nothing except for the backlighting.

Wireless rain alarm op amp type

I have a query about the Wireless Rain Alarm in Circuit Notebook on page 84 in the June 2016 issue. IC3 is referred to in the text as an op amp but no type number is given.

Did the author have a specific device in mind or would any 8 pin general purpose op amp suffice? (W. G., Dunedin, NZ.)

● IC3 was labelled TL071 in the original submission. We apologise for leaving that detail out of the circuit published in the magazine.

Having said that, we're not sure that the TL071 is an ideal choice in this case, as its operating voltage range does not extend down to ground. Despite its lower input impedance, half of an LM358 would probably be more suitable. A CMOS rail-to-rail op amp like the LM6482 would be even better.

Hot water sacrificial anode & relief valve

Back in November 2012, you had an excellent article on hot water systems and how to replace the sacrificial anode to extend its life. I replaced the anode in my system 12 years after the house was built. If it wasn't for your article, I would possibly be replacing the tank by now.

I recently posted on a Facebook page (with photos) about members checking their systems for age and to replace the anode. This is the reply I got from one person:

"Coming from a hot water company owner's point of view and installer for over 25 years (that's all I do), it's not worth doing. Ask yourself, is it worth putting your family at risk of getting sick or killed? Yes, the tank will last a little bit longer but at what cost?

(1) You will be running off the steel of the system as the enamel would already have cracked through (tetanus).

(2) The water board recommends 10-year replacement due to the risk of legionella at the bottom of the tank.

(3) After 10 years, the tanks cost more money to run and are so full up with rubbish the element is encrusted (full of sludge at the bottom of the tank) which makes the tank use more power (trying to heat through all that calcium build up). Note that we sometimes can't drain them they have so much sludge in them.

(4) Tanks after 10 years start to block up pipe work and expensive valves down the line and sometimes warrant pipe replacements due to that calcium build up.

(5) The relief valve must be replaced every five years due to the calcium as your tank will become a bomb. After 10 years the tank has so much calcium build up just one piece could block that valve overnight and kabooooom. You'll know that noise in the middle of the night that you thought was a gun but was in fact someone's tank over 10 years old".

Your thoughts please. (W. S., via email).

● Clearly, you replaced your anode in time although we have seen anodes further gone from the photo that you sent.

Provided the relief valve is working, a hot water tank will not explode. The relief valve will normally release a few litres every time the tank comes up to temperature. You can easily check that this happens. You should also manually operate the relief valve every six months or so. Apart from that, if the anode is replaced every five years or so, you should get at least 15 years' life or more.

Yes, sludge does build up in the bottom of tanks but the heating element is above this and normal convection currents in the tank would

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Ask SILICON CHIP

. . . continued from page 102

keep it clear. We cannot see why the element would use any more power, even if there is a build-up of sludge. Its power consumption is easily checked. Elements do fail but replacements are not expensive. It is a five-minute job for an electrician.

On the other hand, you can now buy stainless steel hot-water tanks which do not have have a sacrificial anode. They mostly come with a 10-year warranty but some have a 20-year warranty, so sludge build-up is clearly not a limiting factor on tank life expectancy.

Battery charger wanted for hybrid vehicle

I've recently re-read your past articles on chargers for NiMH batteries for small tool applications. I'm wondering if you have any comments about how to go about charging the 158V NiMH battery pack in a 2007 Honda Civic Hybrid. It consists of about 100 1.5V NiMH cells in series.

I recently acquired one of these vehicles with a failed CVT transmission and I am in the early stages of understanding how it works before replacing the transmission.

Interestingly, the owner's manual says that the car needs to be run at least once a month for the health of the NiMH batteries. Sadly, there is no facility to charge the battery pack from mains in case it can't be driven (eg, if the owner is overseas). It seems

Notes & Errata

Wireless Rain Alarm, Circuit Notebook, June 2016: the type number for IC3, TL071, was left off the circuit diagram on page 84.

Combined Timer, Counter & Frequency Meter, Circuit Notebook, June 2016: in the circuit on page 87, pins 23 and 24 of IC1 are shown swapped. Also, the pot connected to pin 27 should be labelled VR3, not VR1.

Ask SILICON CHIP
. . . continued from page 103

like that should have been a standard feature, given the cost of a replacement battery.

From what I have read, battery life in the Civic Hybrid from this era is not good. Luckily, the battery on this vehicle seems to be OK at the moment. I would like to keep it that way. Yes, it's simpler just to start the car once a month and run it at 2500 RPM until the batteries are back up to full charge but that's far from ideal and it would be easy to forget.

I did come across this item, which may be suitable: www.ebay.com/itm/2006-2011-Honda-Civic-Hybrid-Standard-Grid-Charger-IMA-Battery-Balancer-/351641475458 (P. H., via email).

- We have no experience nor expertise on the Honda Civic Hybrid. Designing a high-voltage charger for this vehicle would be a challenge, both in the actual power engineering involved and sorting out the complex safety interlocks which are bound to be part of the vehicle.

It would seem that if your proposed charger is going to be able to charge the battery in a reasonable time, its power rating will need to be very substantial, possibly in the region of to 1-2kVA.

You might gain some insight by referring to the article we did on the Toyota Prius in the February 2008 issue – see www.siliconchip.com.au/Issue/2008/February/How+To+Get+More+Than+100MPG+From+A+Toyota+Prius

That article showed how to add an extra Lithium battery to greatly increase its electric driving range and effective fuel economy but whether that is an economically viable proposition is open to debate.

Electronic fuse wanted

Have you ever published a project like an adjustable electronic circuit breaker for automotive use (12V DC)? Sometimes when trouble-shooting, I reckon such a thing would come in pretty handy. (M. K., via email).

- We haven't published an electronic fuse but it's worth thinking about.

A 12V light bulb could be used as a current limiter for some testing, especially if the current draw is not too high. The lamp rating to use depends on the current requirements of the circuit being tested. The lamp could be wired across a blown fuse and plugged in as the test fuse. SC

Next Issue

The September 2016 issue is due on sale in newsagents by Thursday 25th August. Expect postal delivery of subscription copies in Australia between August 25th and September 9th.

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- 55mm cut depth @ 90°
- 45° saw head tilt
- 1.2kW/1.6hp, 240V

Order Code: W875

$220

SAVE $22

TiGer 2000S Wetstone Grinder

- German design & technology
- 200mm stone & hone wheels
- 120W, 240V
- Includes straight edge jig, setting gauge & honing paste

Order Code: W869

$229

SAVE $24

WCR-11D Workshop Series Tool Box

Package

- Ball bearing slides
- Key lockable
- Protective drawer liners

WCH-5S

- 6 drawer tool chest
- 600 x 260 x 340mm

WCR-5S

- 5 drawer roller cabinet
- 616 x 330 x 762mm

Order Code: K004

$269

SAVE $39

BS-4A Metal Cutting Band Saw

- 150 x 100mm capacity
- 3 blade speeds
- Mitre vice 45°
- 1/2hp, 240V

Order Code: B022

$399

SAVE $30

HS120 Table Saw

- Ø315mm TCT blade
- 550 x 800 work table
- Tilt arbor 45°
- 3hp, 240V motor

Order Code: W443

$449

SAVE $46

MGP-17 Puller Set with Slide Hammer

- Drop forged jaws
- 15-30mm internal diametre
- 15-80mm external diametre

Order Code: P013

$119

SAVE $26.20

17 PIECE SET

BM-362 Blade Master Linisher Sander

- 50 x 915mm belt
- Quick change belt & wheel system
- 3 work stations
- Head tilts & rotates
- 0.75kW / 1hp, 240V

Order Code: L0925

$1,232

SAVE $33

CM-300 3-in-1 Pressbrake, Guillotine & Rolls

- 300 x 1mm steel capacity
- Cast iron construction
- Handle operates all functions

Order Code: S645

$330

SAVE $22

INCLUDES BENDING PLATES

HP-20 Hydraulic Press

- 20 Tonne
- 110mm ram stroke
- Spring return ram

Order Code: P144

$269

SAVE $28

CHP-60 Hydraulic Chassis Punch Set

- 1.6mm sheet capacity
- Includes 22.5, 28.3, 34.6, 43.2, 49.6, & 61.5mm dies

Order Code: P030

$249

SAVE $53.50

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- MARK

Staff Member

PB-24 Manual Panbrake

- 600 x 1mm capacity
- Fabricated steel
- Adjustable clamp blade
- Multiple finger widths

Order Code: S749

$330

SAVE $22

SRG-24H Manual Sheet Metal Curving Rolls

- 600 x 1mm capacity
- Manual driven rolls
- Cast iron end frames
- Swivel out top roller

Order Code: S089

$396

SAVE $33

CAST IRON END FRAMES

UNIQUE PROMO CODE

SC28J

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